ADA268511

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
June 1993

3. REPORT TYPE AND DATES COVERED
THESIS/DISSERTATION

4. TITLE AND SUBTITLE
THE SEA BREEZE CONVERGENCE ZONE AND ITS RELATIONSHIP TO FAIR WEATHER ELECTRICITY IN EAST CENTRAL FLORIDA

5. FUNDING NUMBERS

6. AUTHOR(S)
2D Lt Sabrina Taijeron

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
AFIT Student Attending: Ohio State University

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/CI/CIA- 93-121

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
DEPARTMENT OF THE AIR FORCE
AFIT/CI
2950 P STREET
WRIGHT-PATTERSON AFB OH 45433-7765

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release IAW 190-1
Distribution Unlimited
MICHAEL M. BRICKER, SMSgt, USAF
Chief Administration

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

14. SUBJECT TERMS

15. NUMBER OF PAGES
96

16. PRICE CODE

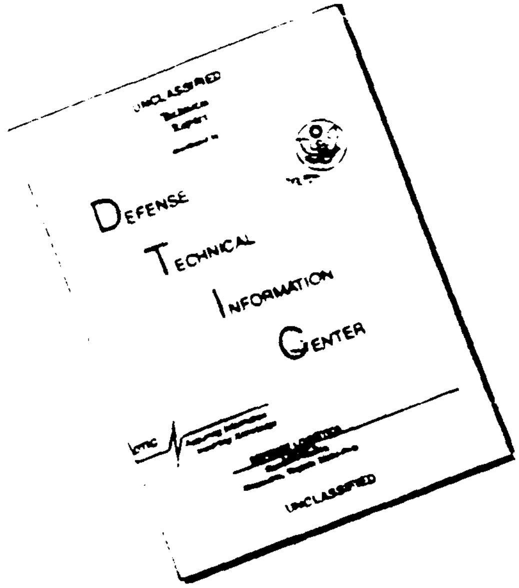
17. SECURITY CLASSIFICATION OF REPORT

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

To Mom, Dad, Roman, Lorriane and Christopher

ACKNOWLEDGEMENTS

First, I would like to thank my family, including Chris, for being there. Their telephone calls and letters were needed. Thanks also goes to U. S. Air Force for giving me the opportunity to pursue a Master's of Science. The assistance and encouragement of the Air Force Institute of Technology personnel (Major Mary Smith and Mary Ellen Ogle) is appreciated. The support of ROTC Detachment 645 and their efforts to lessen my military administrative duties so that I may focus on my studies, was not forgotten.

This research project would not have been possible without the insightful suggestion of Air Force Captain Bill Bauman and Kennedy Space Center Meteorologist Mrs. Launa Maier. I cannot forget Air Force Major Nancy Harris, Patricia Shelton and Russ Boltman (Computer Sciences Raytheon) for spending hours in preparing the data for study.

Thanks also go to The Ohio State University Atmospheric Sciences Program (ASP), for allowing me to participate in the program with constant encouragement and support. The guidance of instructors Dr. John A. Arnfield, Dr. Jay S. Hobgood, Dr. John N. Rayner, and Dr. Jeffery C. Rogers was needed and appreciated. I would like to especially thank my advisor, Dr. Rogers for taking an interest in my research.

I will not forget the incredible mathematical instruction of my good friend Ken Yetzer, and the awesome Fortran instruction of the deceased Mr. Aaron Supowit. Thanks also go Charles Finley because of his constant effort to keep me laughing, and Joe Tegtmeyer's assistance, especially with the IBM compatible 486/DX monster. This section will not be complete until I especially thank Derek A. West for his undying encouragement when times got tough.

VITA

October 27, 1968 .... Born - Agana, Guam; USA

May 28, 1991 .... B.S, United States Air Force Academy, Colorado Springs, Colorado

FIELDS OF STUDY

Major Field: Atmospheric Sciences

Studies in atmospheric electricity

TABLE OF CONTENTS

LIST OF PLATES

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Numerous studies have been conducted on sea breeze related convective activity in east central Florida. However, in this area or elsewhere, there have been no studies on sea breeze electrification. This research focuses on the characteristics and relationship between the fair weather electric field and the sea breeze convergence zone at the KSC/CCAFS, specifically higher sea breeze convergence zone voltages than voltages during onshore flow. Wind sensor and electric field mill data from the CaPE project was analyzed. This study did not reveal any clear indication of a higher electric field during sea breeze convergence. There was no convincing evidence of higher electric field patterns during sea breeze convergence. Therefore, the two phenomena exist, but their interactions would appear to be very weak. This is not to say that the pattern is non-existent and the sea breeze convergence zone does not contribute to the higher than usual fair weather field. The expected interaction might be found in bigger data sets or through other types of analysis.

CHAPTER I

INTRODUCTION

At any given moment, the earth's surface has over 2,000 thunderstorms with lightning striking the ground 100 times per second (Studies in Geophysics 1986). Because we reside in a permanently electrified environment, lightning causes human casualties each year. Furthermore, electrical power outages, forest fires, computer equipment, communication facilities, aircraft, and space transportation vehicles are also damaged by lightning. The state of Florida has more thunderstorms than any other state in the United States (Rogers 1991). Based on the National Weather Service's (NWS) preliminary storm data report, of the 74 people who lost their lives in 1990 after being struck by lightning, 15 of them were hit in Florida (Parisi 1991). The warm moist air from the Atlantic Ocean and the Gulf of Mexico, combined with unstable air masses, dramatically increase the enhancement of thunderstorms in this state. This state's thunderstorm activity as well as the worldwide thunderstorm activity contribute to the earth's surface having a constant electric field of several hundred volts per meter even in fair weather (Studies in Geophysics 1986).

The John F. Kennedy Space Center (KSC) and the Cape Canaveral Air Force Station (CCAFS) are situated along the east coast of central Florida and have a high frequency of sea breezes and thunderstorms during the summer months. The formation of deep cumulus convection in coastal areas during the warm season appears to be strongly influenced by the sea breeze in many subtropical and tropical locations (Pielke and Segal 1986). Furthermore, it has been shown that over relatively narrow islands or peninsulas, daytime convergence of the sea breeze at the center is likely to enhance upward motion and therefore cloudiness as compared with non-island cases (Neumann and Mahrer, 1975; Abe and Yoshida, 1982). These meteorological features, along with blowing dust, smoke and fog, play a role in changing the local electric field. This disrupts scheduled launches from the KSC as well as ground operations. For example, if ground lightning flashes are within five nautical miles of the area, more than fifty activities must be terminated or curtailed for reasons of personnel safety (Nicholson and Jafferis 1988). Lightning has had a dramatic impact on more than one occasion and has caused work stoppages on a regular basis (Nicholson and Jafferis 1988). The primary purpose of the electric field mills (atmospheric electric sensors) is to detect surface electric potential aloft (Weems 1991). However, there are times when the atmospheric electric sensors are electrified without thunderstorms in the immediate area. It is during these situations that the presence of the sea breeze has been noted. The purpose of this research is to discover if a correlation exists between the fair weather electric field and the sea breeze convergence zone.

The meteorological staff at the KSC and the CCAFS are providing the data for the study in return for a copy of the results. The data are obtained as part of the Convection and Precipitation /Electrification (CaPE) Experiment that was conducted in east central Florida during the period of 8 July to 18 August 1991. This project was conducted under the guidance of KSC Electrical Space Engineer Mrs. Launa Maier, Meteorological Instrumentation Department.

1. Problem statement

The onset of a sea breeze is critical for some of the thunderstorms that might develop over the KSC/CCAFS. This project is interested in the characteristics and relationship between the fair weather electric field and the sea breeze convergence zone at the KSC/CCAFS. More specifically, variations in time will be examined for offshore flow, transition zone flow (convergence zone flow), and onshore flow. In short, this project will determine the extent to which the fair weather field and sea breeze convergence zone are related.

2. High electrical field at the KSC/CCAFS

High electric sensor readings occur for three reasons. Dust storms are the first, occurring behind a dry cold front where the winds reach speeds up to thirty knots (Maier 1992; Personal communication). Blowing dust has a charge and this results in the electric sensors reading two or three kv/m, far above fair weather. Secondly, smoke will also cause high electric fields for similar reasons as dust storms. Fortunately, smoke is very isolated and the observer can actually see the smoke over the electric sensor and understand why the electric sensors have high readings. Fog is the third factor. However, KSC scientists and researchers are not sure if the electric sensors are creating an electric field in the fog or if the electric field actually exists in the fog. Furthermore, fog lies directly overhead of the electric sensors. Since it is close to the sensors, there isn't much concern. Concern is expressed when the electric sensors are detecting sources aloft.

3. Importance of lightning forecasts at Cape Canaveral

This research's study region focuses around the CCAFS. This area experiences the majority of its thunderstorm activity during the months of May through October (Nicholson and Jafferis 1988). Air Force weather forecasters must predict lightning within five nautical miles of a specific area with lead times of 30 minutes just for daily ground processing operations (Nicholson and Jafferis 1988). This prevents damage to equipment or injury to people during launch pad, payload, crane, explosive and toxic chemical operations (Parisi 1991), and it brings an end to outdoor work.

Furthermore, the rollout of the space shuttles from the vertical assembly building to the launch complex requires a forecast of a 90 percent probability of no lightning within 20 nautical miles for eight hours or longer (Weems 1991). In addition, delayed work stoppages result from electrical charge that may still linger and occasionally initiate powerful lightning discharges (Weems 1991). Because lightning is common in the area, NASA and the Air force presently have very stringent meteorological criteria which must be met for the launch of space vehicles (Appendix A). For example, no launches will be conducted if fifteen minutes prior to the launch, any of the electric field mills record in excess of 1 kv m^{-1} (Weems 1991). These stringent criteria often result in unnecessary work stoppages of lightning sensitive programs. This research may be able to reduce daily work stoppages by determining if, and to what extent, a correlation exists between fair weather electricity and the sea breeze convergence zone.

Another concern to forecasters is the threat of lightning triggered from high electric field potential aloft, such as occurred with the Atlas-Centaur 67 launch vehicle on March 26, 1987 (Christian et al. 1989). Therefore, to reduce the chances of an spacecraft being hit by either natural or triggered lightning, scientists warn against launching if lightning is detected within 10 nautical miles of the launch site, or planned flight path, within 30 minutes before the launch (Parisi 1991). Launches are also avoided if the planned flight path is through a vertically continuous layer of clouds with an overall depth of 4500 feet or greater, where any part of the clouds are located between the zero degree and minus 20 degree Celsius level and if the planned flight path will carry the vehicle through or within 10 nautical miles of the nearest edge of any cumulonimbus cloud (Parisi 1991). A more detailed listing of forecasting constraints for natural and triggered lightning may be found in Appendix A.

4. Summary of central Florida weather

In order to better understand the climatology of Florida, a brief description is presented. In the summer, the north-south oscillation of the Atlantic/Bermuda high influences the locations and severity of thunderstorm development (Foote 1991). Studies indicate an interaction between synoptic wind and sea breeze circulation in determining the timing and locations of convective activity (Foote 1991). Thus, the sea breeze circulation and normal patterns of Florida convection assume different characteristics depending on whether the prevailing low-level flow has an onshore, offshore, or alongshore component (Foote 1991).

Generally, onshore flow (SW flow) along the Gulf coast may drift eastward (usually in NNE-SSW lines) across the CaPE region. It is more unstable air, contains deeper moisture, and more large-scale upward vertical motion than that from other quadrants (Foote 1991). Furthermore, due to this process, a significant lightning maximum is depicted along the east coast.

Onshore flow (NE flow) along the Atlantic coast is characterized by a shallow low-level maritime moist layer, capped by a subsidence layer with dry conditions aloft; this flow along the Atlantic coast normally generates less vigorous convection, which results in less lightning (Foote 1991).

Alongshore flow (NW flow) has little influence and does little to impede or aid the progress of the sea breeze; it injects dry continental air into the region (Foote 1991). However, isolated deep convection may result along both coasts in regions of sea-breeze convergence (Foote 1991).

SE flow is conditionally unstable and contains deeper moisture than either NW or NNE flow; furthermore, as the sea breeze moves inland under this regime, towering cumulus may occur over the Cape and Merritt Island (occasional lightning producers) during mid-morning (Foote 1991). This results in main thunderstorm activity concentrating on the sea breeze convergence zone on the mainland east of, or in, the St. Johns River valley (Foote 1991).

Light and variable conditions occur 10-15% of the time and pose the greatest forecast problem because, along with the sea breeze, river breezes generate convergence zones on Cape Canaveral and Merritt Island, and if conditions are favorable, clouds may develop into lightning producing storms by mid-morning (Foote 1991). To complicate things even further, both a west coast and east coast sea breeze are generated and a slow progression of both sea breezes toward the center of the state are possible (Foote 1991).

5. Discussion of CaPE experiment

The Convection and Precipitation/Electrification (CaPE) experiment was conducted in east central Florida during the period 8 July to 18 August 1991. More than one hundred scientists from the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, as well as scientists from 25 National Aeronautics and Space Administrations (NASA), the U.S. Air Force, and the Federal Aviation Administration (FAA), tracked thunderstorms to study electric fields in the clouds, storm evolution, and rainfall particles (Parisi 1991). The experiment was designed to focus on five objectives that have been the basis of extensive research activity in recent years. The themes are defined as follows: (1) identification of the relationships among the co-evolving wind, water, and electric fields within convective clouds; (2) determination of the meteorological and electrical conditions in which natural and triggered lightning can (and cannot) occur, and understanding the initiation and propagation of lightning; (3) development of mesoscale numerical forecasts (2-12 hr) of wind, clouds, and thunderstorms, employing data assimilation; (4) improving techniques for performing short-period forecasts (nowcasts, < 2 hr) of convection initiation, downbursts, and tornadoes; and (5) the characterization of precipitation particles and remote estimation of rainfall (Foote 1991).

The study region for this research on sea breeze related electrification is the same as the CaPE experiment and will be discussed in detail, in chapter three. Chapter two contains a review of fair weather electricity, sea breezes, and a literature search relevant to this research. Data and methods will be presented in the third chapter, with chapter four containing a discussion of the results. Lastly, a summary of the research completed and suggestions for further study will be presented in chapter five.

CHAPTER II

BACKGROUND MATERIAL AND RELEVANT LITERATURE REVIEW

1. Review of sea breezes

Sea and land breezes are caused by differential heating of land and water. When both land and water are exposed to the same intensity of solar radiation, the land surface warms more quickly than the water surface (Moran and Morgan 1991). The land heats the overlying air, thereby lowering air density. However, the air above the water is much cooler. Therefore, as shown in Figure 1, a local horizontal air pressure gradient develops between land and water, with the highest pressure over the water surface. Cool air sweeps inland due to airflow moving down the pressure gradient. Furthermore, continuity requires a return airflow directed from the land to the water, with warm air rising over the land and cold air sinking over the water (Moran and Morgan 1991).

A land breeze is the reversal of the surface winds. At night, radiational cooling chills the land surface more than the water surface, and a horizontal gradient in air density gives a rise to a horizonal air pressure gradient that is directed from land to sea. Thus, a cool offshore breeze develops, along with a return airflow aloft, whereby air subsides over the land and rises over the water (Moran and

Morgan 1991).

Land breezes reach maximum strength just before sunrise but tend to be weaker than sea breezes while sea breezes generally do not reach maximum strength until midafternoon (Moran and Morgan 1991). Sea breezes are generally restricted in depth by the height of the mixed layer (1 or 2 km) and extend inland from the coast 10-50 km (Reible et al. 1993). Furthermore, wind speeds will increase as the sea breeze moves inland (Maier 1992; Personal communication).

Observational studies of the Texas coast sea breeze show that it is best developed at about 1500 local time, when the mean onshore breeze has a velocity of 6 m/s, with the return flow averaging 3 m/s (Schaefer et al. 1992). Convective showers most likely develop in the area of strongest convergence about one or two hours later; in addition, low-level winds along coastlines are usually affected by the sea breeze, even when large-scale synoptic influences are present (Schaefer et al. 1992).

Land and sea breezes typically develop and diminish so rapidly that they are not significantly influenced by the Earth's rotation (Moran and Morgan 1991). However, in some localities, the Coriolis effect is responsible for a gradual shift in the direction of a sea breeze through the course of a day, but the magnitude of the Coriolis is always weaker than the pressure gradient force.

2. Review of fair weather electricity

In the introduction, it was mentioned that worldwide thunderstorm activity contributed to the earth's surface constant electric field (the global circuit) of several hundred volts per meter even in fair weather. An explanation of the global circuit will be presented here.

It is known that thunderstorm clouds are electrified. However, it is far less well known that the fair weather atmosphere is also electrified and that thunderstorms generate this electrification (Pierce 1992). A thunder storm cloud is electrified so that the upper portions are positively charged and the lower parts negatively charged. However, below the cloud there is an interchange of electricity with the Earth by three main processes: (1) cloud-to-ground lightning; (2) point discharge and conduction currents; and (3) rain (Pierce 1992).

Pierce states that these three main processes transfer negative electricity to ground at a rate of about 1 ampere (A) per storm. Wilson's (1925, 1926) original solution of how the Earth maintains it's negative charge considered only conditions below the cloud. Later, he discovered that a thunderstorm transfers positive charge toward the conducting upper atmosphere, this theory is known as the global circuit (Pierce 1992). In the upper atmosphere, the charge is redistributed laterally to the fair weather areas so that the thunderstorms effectively supply the driving potential of 3 X

10^5 V for the fair weather currents, see Figure 2 (Pierce 1992). The upper positive charge in the cloud creates a strong field, driving positive ions upward (Pierce 1992). Wilson's concept is generally accepted even though the exact morphology of the currents in the upper atmosphere is still somewhat uncertain (Pierce 1992).

Pierce states that over land, beneath a thunderstorm cloud, potential gradient (or field) is directed predominantly vertically, fluctuates in magnitude, and often has a peak magnitude of about 10 kV m^{-1}. Furthermore, the gradient varies in sign but is usually negative, indicating a dominant negative charge in the lower portion of the cloud overhead; and as the storm approaches, the positive fair weather gradient often increases in size, then decreases and passes through zero to become strongly negative when the cloud is overhead (Pierce 1992). Figure 3 illustrates these field change fluctuations of a very weak storm that approached within 7 km of the recording site. In this figure, Pierce showed the reversal of the potential gradient from positive to negative as the storm moves nearer and the abrupt positive changes caused by close lightning.

Pierce also states that measurements of fields within thunderstorm clouds are difficult; but, generally fields within clouds are about 50 to 200 Kv m^{-1}. Also, there is often an increase in field when the cloud is entered, and there are localized regions of extremely high fields in the cloud, some as high as 400 kV m^{-1} (Pierce 1992).

Thus, the solid and liquid Earth and its atmosphere are almost permanently electrified; the surface has a net negative charge, and there is an equal and opposite positive charge distributed throughout the atmosphere above the surface (Studies in Geophysics 1986). In fair weather, there is an electric field of 100-300 v/m near the ground that is maintained by worldwide thunderstorm activity (Pierce 1983). Cloud-to-ground lightning transfers negative charge to the ground, and the point discharge currents under a storm transfer positive space charge to the atmosphere.

3. Relevant sea breeze studies

Past studies from southern Florida (Watson and Blanchard 1984; Cunning et al. 1982; Cooper et al. 1982; Ulanski and Garstang 1978) indicate that surface winds have the potential to be useful for predicting new thunderstorm growth. It is safe to assume that during the summer in Florida, most convective development is triggered by processes in the boundary layer. The life cycle of these thunderstorms is likely to be reflected in the surface wind field beneath the storms. This assumption, however, does not always hold true for thunderstorm development in a more midlatitude environment (Watson et al. 1983) or during other seasons in Florida. Thus, typically, studies on surface wind convergence at the KSC focused on cloud-to-ground lightning prediction (Watson et al. 1991; Watson et al. 1987) and are not emphasizing sea breeze related electrification. More specifically, the relationship between the sea breeze convergence zone and its effect on the electric field potential aloft.

Other studies have emphasized the importance of the interaction between the synoptic wind field and the sea-breeze circulation in determining the timing and location of convective activity across the Florida peninsula (Byers and Rodebust 1948; Gentry and Moore 1954; Estoque 1962; Frank et al. 1967; Neumann 1971; Pielke 1974; Blanchard and Lopez 1985; Waston et al. 1987). Lastly, scientists have shown that the spatial cloud-to-ground lightning distribution in central Florida is determined in large part by this interaction (Lopez and Holle 1987).

4. Relevant fair weather electricity studies

Evidence in the late 1960s and early 1970s indicated that the presence of sea-salt particles added to the instability of certain parcels of air over the sea, causing ascent, and perhaps leading directly or indirectly to cloud formation (Woodcock et al. 1963). Blanchard (1963) postulated, on the basis of laboratory experiments with salt water, that whitecap activity over the open ocean would produce positive atmospheric space charge by means of highly positively charged water drops ejected into the air by the bursting of air bubbles at the air-sea interface (Gatham and Hoppel 1970). Later Blanchard observed high values of positive space charge during periods of onshore winds on the island of Hawaii; these values were presumably due to the bubble electrification process in the surf zone (Gatham and Hoppel 1970).

Thus, there are no studies on surface convergence in relation to the electric field potential aloft either at the KSC or elsewhere. Thunderstorm producing sea breeze convergence studies have been done but studies in sea breeze convergence in relation to the electric field potential aloft have not.

However, changes do occur in the electric field around the KSC in conjunction with the fair weather sea breeze onset. Salt water bubbles burst and add positive ions to the air (Blanchard 1966). The ions are on aerosols and stay aloft better in converging, rising air, lasting for extended periods of time and producing higher than usual electrical readings. As the sea breeze enters the coast, convergence begins to occur, and as the sea breeze moves inland, the zone of convergence stays along its leading edge, the sea breeze front (Maier 1992; Personal communication). The sea breeze front defines the edge of the inland penetrating marine air mass (Pielke and Segal 1986). When the sea breeze moves inland the convergence area is cut off from the surf (ion source region). Therefore, an enhancement of the fair weather electric field occurs during sea breeze convergence. The background level may be 300-400 v/m and then it will jump to about 700-800 v/m (Maier 1992; Personal communication). Volts per meter is the measurement unit for the electric field (Wahlin 1986). As convergence moves further inland the voltage once again drops and returns to previous levels.

CHAPTER III

DATA AND METHODOLOGY

1. STUDY REGION

This project uses CaPE data gathered in the vicinity of the KSC and the CCAFS. Figure 4 displays a map of the general study region, presenting the locations of all the meteorological sensors including the wind towers and the electric field mills. The study region has three rivers, the Indian River, the Banana River, and the St Johns River. These rivers help set up local water-land breezes which initiate convective cloud development. In order to characterize the relationship between fair weather electricity and sea breezes, wind sensor data and atmospheric electric sensor data must be analyzed. A description of each type of data will be discussed in following sections.

2. Wind sensor data

Wind sensor data or wind tower data is primarily used to indicate the onset of a sea breeze or thunderstorm on the coast. The KSC/CCAFS has 51 wind sensor systems, and the 790-km^2 analysis area is shown in Figure 5. Although individual towers have varying heights and instrumentation, this study used winds mainly sampled at 3.65 m (12 ft), which is one of the lower levels for all sites that contains wind direction, wind speed, wind gusts, and wind deviation. Plates I and II located in Appendix B display photographs of the full-scale wind tower #0001 and a close-up of its equipped wind sensor instrumentation. The wind data are recorded in increments of five minute averages.

The onset of a sea breeze is critical for some of the thunderstorms that might develop over the study region due to land-water breezes initiating convective cloud development. In the morning when the land starts heating up, not only is the ocean cooler but so are the rivers. Therefore, both sea breezes and river breezes evolve. For example, wind sensors #0001, #0003, and #0006 may make a turn to the east first. At the same time, the wind sensors east of the river start to turn to the west (westerly wind) due to the relatively lower river temperatures resulting in a river breeze similar to the sea breeze on this side of Cape Canaveral. This same phenomena happens on Merritt Island and the KSC. The wind sensors start to show an easterly wind from the St Johns and Indian Rivers, where on the other side a westerly wind emerges resulting in a line of convergence that starts setting up over the center of Cape Canaveral and over the center of Merritt Island and the mainland. The strongest convergence is typically before noon along Merritt Island and Cape Canaveral; otherwise, by afternoon, the thunderstorms caused by the sea breeze will dissipate.

The wind sensors must be used in conjunction with the electric field mills in order to compensate for the river breezes complicating the environment and in linking changes in electrical activity with sea breeze onset. If these rivers did not exist, there would be no westerly component leading to convergence over the study area. Once convergence exists, then the atmospheric electric sensors can be monitored as the first indication that in situ charge is developing.

3. Atmospheric electric sensor data

The primary use of the atmospheric electric sensor data is to indicate an electric field aloft, such as electrified clouds in thunderstorms. The KSC/CCAFS atmospheric electric sensor network comprises 31 electric field mills that constantly monitor the surface electric-field intensity over the entire area of KSC/CCAFS, see Figure 6 for a map of the atmospheric electric sensors (Foote 1991). This network measures electric fields at sixty Hz resolution (Foote 1991). The data were recorded as 10 samples per second for each electric field mill. However, for this project the data was retrieved and analyzed as one minute averages.

In this study, ground based electric field mills are the source of data on the electric field aloft. Other electric field measuring devices such as rockets, balloons, and airplanes are not used. The ground based rotating vane electric field mill senses charge induced on different plates, or stators, alternately shielded from and exposed to the atmospheric electric field by a grounded rotor, see Plate III for photograph (Rust 1988). Furthermore, geometrically opposite sensor plates are connected to each other, and each pair in turn is connected to the inverting input of an amplifier (Rust 1988). Therefore, the amount of charge induced on the stators, and thus flowing in the amplifier circuit, is a function of the magnitude of the local electric field (Rust 1988).

Ground based electric field mills are designed to measure from about 100 v m^{-1} (fair weather) to 20 kV m^{-1}, intense thunderstorm cloud overhead (Rust 1988). In addition, fields at the Earth generally do not exceed about 15 kV m^{-1} because they are limited by space charge originating in corona breakdown from vegetation and other projections above ground (Rust 1988).

4. Wind sensor data analysis

The data analysis process consisted of two parts, (1) identification of sea breeze onset time based upon the wind sensor data and (2) analysis of the electric field variations based upon the electric field mill sensor data during and after sea breeze onset. The wind sensor data analysis will be discussed first.

Of the 51 wind sensors, only those located near the coast and near an adjacent electric field mill were analyzed. Since many wind sensors were missing data, due to data collection failures, only wind sensors #0003, #0110, and #0112 were analyzed. With a criteria of wind direction between -45° (northwesterly wind) to 180° (southerly wind), due to the eastward protruding tip of Cape Canaveral allowing a more lenient sea breeze wind direction, three tables of 13 sea breeze onset days was assembled. Change in the local wind direction and magnitude were sought in order to identify the time of sea breeze onset. The criteria of wind speed variations of 2 to 3 kt was used due to the CaPE wind tower data set for non-sea breeze days having zero to 1 kt variations. Thus, it was deemed sufficient that 2 to 3 kt variations be used. Winds were checked every five minutes to see if wind shifts occurred. Data were only analyzed from 13:00 Z to 20:00 Z since the sea breeze at the KSC/CCAFS usually occurs during these hours. Of the 42 days of data collected during the CaPE experiment, sea breezes were identified on only 13 days.

Table 1 (Appendix C) shows the sea breeze onset times for wind tower #0003. A summary of sea breeze onset times for wind tower #0110 and #0112 is also shown in Table 2 and Table 3, respectively. The most pronounced sea breeze onset days for all three of these wind towers were Julian dates 91200 and 91203. Most pronounced sea breeze onset days is defined as (1) wind direction within -45° to 180°, (2) having wind speed variations of at least 2 to 3 kt, and (3) having sea breeze onsets lasting for more than 60 minutes. Note that Tables 1-3 list all sea breeze onset times, in regard to wind direction and magnitude, whether the onsets lasted for 60 minutes or not. However, times acquiring all three categories were only further analyzed. Figures 7-12 (Appendix D) graphically displays the wind direction and magnitude for these days, from 13:00 Z to 20:00 Z.

5. Atmospheric electric sensor data analysis

After a list of sea breeze onset times and days was established (Tables 1-3), an analysis was conducted of the electrical field variations before, during and after sea breeze convergence. In this study, only electric field mills adjacent to the three established wind towers (see above section) were used. Of the 31 mills available, this included atmospheric electric sensors: #08, #09, #12, #13, #16, #26, #28, and #30. The atmospheric electric sensor data were only analyzed from 13:00 Z to 20:00 Z, similar to the wind sensor data. It should be noted that this data set also had some missing data. The electric field mill data were analyzed in two steps: (1) time series of the voltages for all eight electric field mills were plotted for each established sea breeze day, and (2) means and standard deviations were computed only for those mills and days containing the desired pattern. The graphing and statistical package used was the Quattro Pro version 3.0 software, and results will be shown in the next chapter.

CHAPTER IV

RESULTS AND DISCUSSION

Due to land-water breezes initiating convective cloud development, the onset of a sea breeze is critical for some of the thunderstorms and convergence zones that might develop in the study region. This project looks for a pattern whereby changes in the electric field occur with the fair weather sea breeze onset. Ions from salt water bubbles are on aerosols that more successfully stay aloft in converging, rising air, lasting for extended periods of time, and producing higher than usual electrical readings. It would seem that an enhancement of the fair weather electric field occurs during sea breeze convergence. The expected background electric field may resemble a pattern varying randomly around at 300-400 v m^{-1}, for offshore flow, and then it may jump to about 700-800 v m^{-1} during convergence or transition zone flow. As the sea breeze moves inland, the convergence area is cut off from the surf (ion source region) and the voltage once again drops and returns to previous levels during the onshore flow. A time series data plot of this expected pattern is shown in Figure 13.

The time series voltages were plotted for all thirteen sea breeze days. This displayed the electrical activity from

13:00 Z to 20:00 Z. After the time series data were plotted for sea breeze days, three groupings were established, (1) those days in which unusually high or unusually low electric voltages occur during onshore flow, (2) those in which the electric field does not change during sea breeze onset or afterwards, and (3) sea breeze days with some periods of time, not necessarily during sea breeze, when the electrical field values increase beyond background fair weather levels. These are discussed in the following three sections.

1. Sea breeze days with extreme voltage readings

Julian day 91201 is a good example of sea breeze days that had unusually high or unusually low electric field voltages, occurring at seemingly random times (Figures 14-18). Note that the sea breeze onset times occurred differently for each wind sensor (Tables 1-2), and that none of the convergence zone voltages were close to the expected 700-800 v m^{-1}. In fact, some convergence zones are negative. There are also some days that acquired two sea breeze onsets. Note that each wind tower corresponds only to specific adjacent atmospheric electric sensors. For example, wind sensor #0003, with adjacent electric field mills #28 and #30, registered sea breeze onsets, using all three criteria, at 1135 local time (15:35 Z) and 1335 local time (17:35 Z) (Figures 17-18). Sea breeze onset at wind sensor #0110, with adjacent electric field mills #13, #16, and #26, occurs at 1050 local time (14:50 Z), see Figures 14-16. Some electrical fields measured higher than 4,500 v m^{-1} (Figures 15 & 18), and as low as -8700 v m^{-1} (Figure 15). Thus, these sporadic electric field variations did not resemble the expected pattern, of low positive voltages, on sea breeze days.

The fluctuations of the electric field are possibly due to convective development that began at 11:00 Z, as bands of showers and thunderstorms moved ashore in a one hundred mile zone along the east coast centered on Cape Canaveral (Williams et al. 1992). On this day, it seemed that activity was unusually strong for approximately four hours (11:00-15:00 Z) and development continued as this band of showers and associated sea breeze development elsewhere moved rapidly westward across Florida (Williams et al. 1992).

2. Sea breeze days with little electrical field variation

Julian dates 91200 and 91203 had the most pronounced sea breeze days, as measured using any of the three sea breeze criteria (Chapter III). On these days there were no large positive or negative voltages reported during the sea breeze event. However, even though these days fit the sea breeze criteria, their corresponding electric field did not resemble the electric field pattern by which voltages change during sea breeze onset (Figures 19-34). The electric field stayed at fair weather values (300-400 v m^{-1}) most of Julian day 91200. There was a constant negative recording for all eight electric field mills from 15:00 Z to 16:00 Z. In this case where convective development and sea breeze interactions remain weak for a day, Maier (1992: Personnel communication) has suggested that a negative field might be linked to insect or animal interactions with the instrumentation. Spiders creating webs on the rotating stators or birds actually landing on the instrumentation, might be a possible explanation for such large negative fields since the study region is located on a wildlife refuge.

Julian day 91203's electrical voltages also stayed mostly in the fair weather field. The only exceptions were electric field mills #13, #16, and #26 which correspond to wind tower #0110 (Figures 30-32). They recorded electric fields as high as 6,300 v m^{-1} and low as -4000 v m^{-1} between the hours of 13:00-14:30 Z. Morning showers were produced due to onshore flow, possible between 13:00-14:30 Z; but overall conditions remained generally suppressed with weak convective development in the study region as the sea breeze moved inland (Williams et al. 1992). Furthermore, it is not known why, on this day, the surface electric field mills did not begin recording until 13:58 Z (Williams et al. 1992). Therefore, the morning electrical fluctuations may have resulted from instrument failure.

3. Sea breeze days with electric field variations during onshore flow

In this last group of days, electrical field changes seemed to resemble those expected for sea breeze convergence events, but in fact a linkage to sea breeze onset could not be clearly identified. Julian days 91227, 91228, and 91204 are characteristic of this type of day, with 91204 being the best example.

Julian day 91227 (Figures 35-39) had some electric field mills that had electrical field changes resembling the expected pattern but instead of dropping back down again to fair weather values after the sea breeze onset, the electric field would continue to increase. In particular, Figure 35 has an onshore flow at 18:25 to 20:00 Z. In this example, the voltages start off in fair weather then increase to approximately 500 to 600 v m^{-1} during convergence zone flow before reaching onshore flow. However, the electric field continued to rise (approximately 650 v m^{-1}) then drop back down to fair weather values at 19:00 Z then suddenly increase to approximately 800 v m^{-1}. Figures 36-38 show more examples of this behavior; however, Figure 39 does not. In this case higher voltages do occur before onshore flow but the values are as high as 1500 v m^{-1}. Furthermore, the voltages start off around 500 v m^{-1}, higher than fair weather values. Therefore, the expected convergence zone values were not to be this high, and the expected onshore values were not to be this negative.

Julian day 91228's (Figures 40-44) electrical pattern was similar to Julian day 91227. Both days had electric field increases during onshore flow, though 91228 did not increase or fluctuate so sporadically, and not like Julian day 91227 all the electric field mills for Julian day 91228 had the same sea breeze onset pattern.

The last example, Julian day 91204 had several time periods when the electrical field exceeded 500 v m^{-1}. As shown in Figure 45, onshore flow occurred at 18:05-19:00 Z. Convergence zone (17:20-18:00 Z) voltages were higher than the fair weather values, peaking at 616.4 v m^{-1}. However, during onshore flow the voltages continue to increase sporadically to 812.8 v m^{-1}. Adjacent electric field mill #30 (Figure 46) had a different pattern with the convergence zone (17:15-18:00 Z) voltages, peaking at 552.4 v m^{-1}. These values were not as high as the voltages for electric field mill #26 (Figure 45), but they were greater than its onshore flow (18:05-19:00 Z) voltages that peaked at 569.8 v m^{-1} and sporadically dropped to fair weather values. Voltages began increasing after 19:00 Z. This might be due to a weak sea breeze formation that only lasted 15 minutes. On this day, weak convective activity dominated the area (Williams et al. 1992). Performing a statistical analysis on the one minute electric field averages, for all eight mills from 13:00-20:00 Z, resulted in this day's mean voltage for electric field mills #28 and #30 being 590.1 and 413.6 v m^{-1} respectively, see Table 4 in Appendix B. The table also lists the standard deviations as well as maximum and minimum voltages. For this date, further statistical analysis was completed for only the convergence and sea breeze zones, Table 5. For mill #28, the mean electric field voltage during convergence flow were not the expected higher values during convergence flow. The mean convergence zone value was less than mean sea breeze zone value. However, mill #30 did resemble the expected pattern. The mean convergence zone value was higher than the mean sea breeze zone value, but the difference was not significantly greater.

4. Discussion

Only one sea breeze day had an electric field time series pattern that even closely resembled the hypothesized pattern in which voltages rise sharply during the onset of the sea breeze. This project's data set suggest that a link between electrical field and sea breeze convergence is weak at best and perhaps non-existent. Failure to verify the hypothesis may be due to a poor sea breeze event criteria. However, sea breeze onset times were rechecked using more stringent criteria, wind directions between 50-130° for wind tower #0003 and wind directions between 30-130° for wind towers #0110 and #0112 with wind directions required to last 30 minutes instead of the original 60 minutes. This reanalysis produced the same thirteen sea breeze days; however, these sea breeze durations were much shorter.

Furthermore, the electric field sensors during the CaPE project were over estimating the ambient electrical field values. A test was used to validate the absolute calibration of the field mills, and was conducted by the Computer Sciences Raytheon (CSR) Operational Analysis Section (CSR 3200) and the NASA KSC Instrumentation and Measurements Branch (TE-CID-3) during September and October 1990 (Maier and Maier 1992). This involved the installation of a calibrated, flush mounted field mill in close proximity to an existing operational field mill so that data could be collected simultaneously from both instruments while they were exposed to similar electric field conditions (Maier and Maier 1992). As a result, the actual ambient electric field was overestimating by a factor of 1.36 (Weber 1992). This was not be a concern since this applies to all the electric sensors. It should be noted that field mills, like any other meteorological instrument, must be calibrated periodically in order to provide an accurate absolute measure of the electric field intensity (Maier and Maier 1992).

CHAPTER V

CONCLUSION

This project described the characteristics and relationship between fair weather electricity and sea breezes at the KSC/CCAFS. The data were analyzed by first estimating the onset of sea breezes, based upon the wind sensor data, and then analyzing the electric field variations based upon the atmospheric electric sensors data for offshore, convergence, and onshore flow. This study did not reveal any clear indication of a higher electric field during sea breeze convergence due to the addition of positive ions to the air that are attached and carried on aerosols originating on salt water bubbles. As the sea breeze sets in on the coast, convergence begins to occur, and as the sea breeze moves inland the zone of convergence stays along its leading edge (the sea breeze front). However, as the sea breeze moves inland the convergence area is cut off from the surf (ion source region). Thus, at sea breeze onset and convergence, a brief enhancement of the fair weather electric field occurs. However, this project did not identify any convincing evidence of these electric field patterns. Therefore, the two phenomena exist, see Chapter IV, but their interactions would appear to be very weak. This is not to say that the pattern is non-existent and that the sea breeze convergence zone does not contribute to the higher than usual fair weather field. The expected interaction might be found in bigger data sets or through other types of analysis.

For example, the wind and electric field mill data may be examined from other perspectives, possibly an examination of electric field variations during high or low tides. During high tide it is noticed that the water level will be closer to the electric field mill. Furthermore, during tropical storms or hurricanes, large swells occur and the ocean is relatively rough allowing the water level to come up further on the beach than normal. Sea state information would be needed for further evaluation. Secondly, a consideration of the strength of convergence might be evaluated. This would require examining wind speed variations. Lastly to account for more accurate sea breeze onset times, a study may be performed that allows an inland wind sensor to be monitored before, during, and after convergence. This will reveal a more accurate sea breeze onset time due to the analyzer being able to back track to a period over the coast.

APPENDIX A

Forecasting constraints for natural and triggered lightning at the John F. Kennedy Space Center and the Cape Canaveral Air Force Station

(from Weems 1991)

THE LAUNCH WEATHER OFFICER MUST HAVE CLEAR AND CONVINCING EVIDENCE THE FOLLOWING CONSTRAINTS ARE NOT VIOLATED:

A. DO NOT LAUNCH IF ANY TYPE OF LIGHTNING IS DETECTED WITHIN 10 NM OF THE LAUNCH SITE OR PLANNED FLIGHT PATH WITHIN 30 MINUTES PRIOR TO LAUNCH UNLESS THE METEOROLOGICAL CONDITION THAT PRODUCED THE LIGHTNING HAS MOVED MORE THAN 10 NM AWAY FROM THE LAUNCH SITE OR PLANNED FLIGHT PATH.

B. DO NOT LAUNCH IF ANY OF THE PLANNED FLIGHT PATH WILL CARRY THE VEHICLE:

1. THROUGH CUMULUS CLOUDS WITH TOPS THAT EXTEND TO AN ALTITUDE AT OR ABOVE THE PLUS 5 DEGREE CELSIUS LEVEL; OR

2. THROUGH OR WITHIN 5 NM OF CUMULUS CLOUDS WITH TOPS THAT EXTEND TO AN ALTITUDE AT OR ABOVE THE MINUS 10 DEGREE CELSIUS LEVEL; OR

3. THROUGH OR WITHIN 10 NM OF CUMULUS CLOUDS WITH TOPS THAT EXTEND TO AN ALTITUDE AT OR ABOVE THE MINUS 20 DEGREE CELSIUS LEVEL; OR

4. THROUGH OR WITHIN 10 NM OF THE NEAREST EDGE OF ANY CUMULONIMBUS OR THUNDERSTORM CLOUD INCLUDING ITS ASSOCIATED ANVIL.

C. DO NOT LAUNCH IF, FOR RANGES EQUIPPED WITH A SURFACE ELECTRIC FIELD MILL NETWORK, AT ANY TIME DURING THE 15 MINUTES PRIOR TO LAUNCH TIME, THE ONE MINUTE AVERAGE OF ABSOLUTE ELECTRIC FIELD INTENSITY AT THE GROUND EXCEEDS 1 KILOVOLT PER METER WITHIN 5 NM OF THE LAUNCH SITE UNLESS:

1. THERE ARE NO CLOUDS WITHIN 10 NM OF THE LAUNCH SITE; AND,

2. SMOKE OR GROUND FOG IS CLEARLY CAUSING ABNORMAL READINGS.

NOTE: FOR CONFIRMED INSTRUMENTATION FAILURE, CONTINUE COUNTDOWN.

D. DO NOT LAUNCH IF THE PLANNED FLIGHT PATH IS THROUGH A VERTICALLY CONTINUOUS LAYER OF CLOUDS WITH AN OVERALL DEPTH OF 4,500 FEET OR GREATER WHERE ANY PART OF THE CLOUDS ARE LOCATED BETWEEN THE ZERO DEGREE AND THE MINUS 20 DEGREE CELSIUS TEMPERATURE LEVELS.

E. DO NOT LAUNCH IF THE PLANNED FLIGHT PATH IS THROUGH ANY CLOUD TYPES THAT EXTEND TO ALTITUDES AT OR ABOVE THE ZERO DEGREE CELSIUS LEVEL AND THAT ARE ASSOCIATED WITH DISTURBED WEATHER WITHIN 5 NM OF THE FLIGHT PATH.

F. DO NOT LAUNCH THROUGH THUNDERSTORM DEBRIS CLOUDS, OR WITHIN 5 NM OF THUNDERSTORM DEBRIS CLOUDS NOT MONITORED BY A FIELD MILL NETWORK OR PRODUCING RADAR RETURNS GREATER THAN OR EQUAL TO 10DB.

G. GOOD SENSE RULE

IF HAZARDOUS CONDITIONS EXIST THAT APPROACH THE LAUNCH CONSTRAINT LIMITS OR IF HAZARDOUS CONDITIONS ARE BELIEVED TO EXIST FOR ANY OTHER REASONS, AN ASSESSMENT OF THE NATURE AND SEVERITY OF THE THREAT SHALL BE MADE AND REPORTED TO THE TEST DIRECTOR OR LAUNCH DIRECTOR.

DEFINITIONS:

1. DEBRIS CLOUD - ANY CLOUD LAYER OTHER THAN A THIN FIBROUS LAYER THAT HAS BECOME DETACHED FROM THE PARENT CUMULONIMBUS WITHIN 3 HOURS BEFORE LAUNCH.

2. DISTURBED WEATHER - ANY METEOROLOGICAL PHENOMENON THAT IS PRODUCING MODERATE OR GREATER PRECIPITATION.

3. CUMULONIMBUS CLOUD - ANY CONVECTIVE CLOUD THAT EXCEEDS THE MINUS 20 DEGREE CELSIUS TEMPERATURE LEVEL.

4. CLOUD LAYER - ANY CLOUD BROKEN, OVERCAST LAYER, OR LAYERS CONNECTED BY CLOUD ELEMENTS; E.G., TURRETS FROM ONE CLOUD TO ANOTHER.

5. PLANNED FLIGHT PATH - THE TRAJECTORY OF THE FLIGHT VEHICLE FROM THE LAUNCH PAD THROUGH ITS FLIGHT PROFILE UNTIL IT REACHED THE ALTITUDE OF 100,000 FEET.

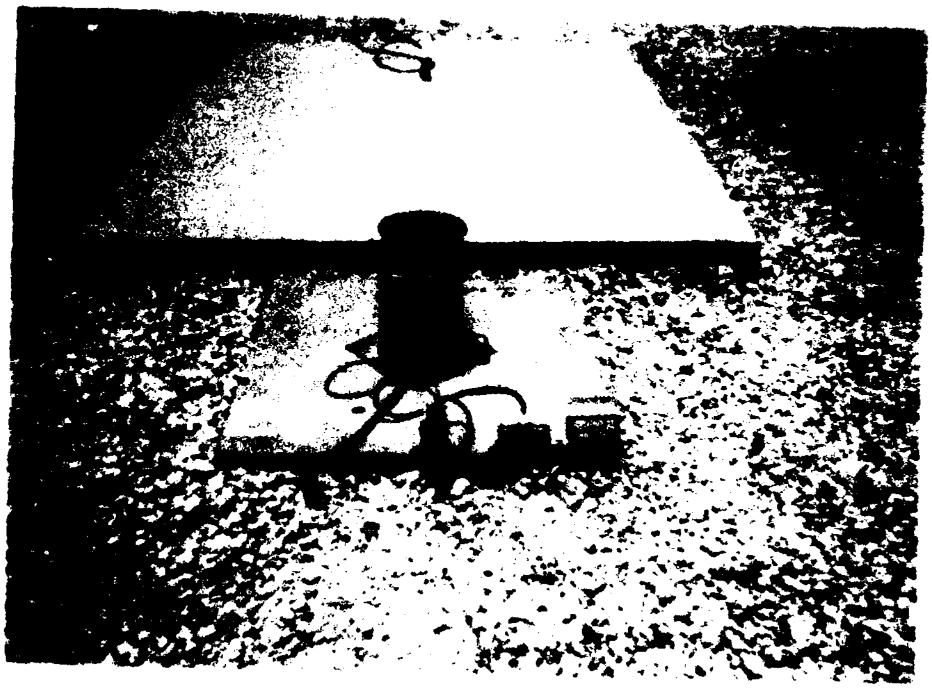
6. ANVIL - STRATIFORM OR FIBROUS CLOUD PRODUCED BY THE UPPER LEVEL OUTFLOW FROM THUNDERSTORMS OR CONVECTIVE CLOUDS. ANVIL DEBRIS DO NOT MEET THE DEFINITION IF IT IS OPTICALLY TRANSPARENT.

APPENDIX B

PLATES

PLATE 1

PLATE III



APPENDIX C

TABLES

TABLE 1. Sea Breeze Initiation for Wind Sensor #0003
Adjacent Electric Field Mills: #28 & #30

JULIAN DATE	LOCAL TIME	TIME PERIOD OF SEA BREEZE (MINUTES)	WIND DIRECTION (DEGREES)	WIND SPEED (KTS)
91199	1415-1600	105	111 TO 135	3-4
91200	1245-1600	195	28 TO 123	2-11
91201	1135-1315	90	86 TO 119	1-3
	1335-1500	85	-12 TO 134	1-11
91203	1305-1600	175	4 TO 56	2-8
91204	1350	5	61	1
	1405-1500	55	80 TO 138	2-4
	1510-1525	15	118 TO 133	4
	1535	5	134	5
	1545	5	129	5
91215	1240-1345	65	14 TO 114	1-3
	1450-1600	70	47 TO 133	3-5
91216	1435-1600	85	4 TO 91	2-5
91219	0900-1205	185	13-129	2-6
	1340-1600	130	99-132	3-4
91220	1225-1500	155	-6 TO 124	2-4
	1510	5	135	5
	1530-1600	30	121-126	5
91227	1340-1600	140	11-108	3-6
91228	0920-0955	35	-30 TO 7	2-4
	1155-1600	245	-30 TO -1	2-8
91229	1310-1600	170	-30 TO -13	8 14

TABLE 2. Sea Breeze Initiation for Wind Sensor #0110
Adjacent Electric Field Mills: #13, #16, & 26

JULIAN DATE	LOCAL TIME	TIME PERIOD OF SEA BREEZE (MINUTES)	WIND DIRECTION (DEGREES)	WIND SPEED (KTS)
91200	1020-1025	5	121	1
	1055-1100	5	117 TO 125	1
	1255-1315	20	4 TO 39	1-2
	1330-1600	150	78 TO 136	1-8
91201	0915-0925	10	124 TO 131	1
	1050-1230	90	65 TO 124	1-3
	1340-1345	5	65 TO 358	1-3
	1415-1420	5	94 TO 98	1-1
91203	1050-1130	40	-10 TO 41	1-2
	1345-1600	135	30 TO 131	1-5
91207	0910-0940	30	5 TO 131	1-2
	1020-1025	5	79 TO 125	NA
91229	0900-0930	30	-28 TO -12	3-4
	1135-1600	265	-30 TO -1	5-10

TABLE 3. Sea Breeze Initiation for Wind Sensor #0112
Adjacent Electric Field Mills: #08, #09, & #12

JULIAN DATE	LOCAL TIME	TIME PERIOD OF SEA BREEZE (MINUTES)	WIND DIRECTION (DEGREES)	WIND SPEED (KTS)
91199	1510-1530	20	116 TO 136	3-4
	1540-1550	10	104 TO 119	4-5
91200	1235-1600	265	105-334	1-7
91203	1300-1600	180	-28 TO 44	1-7
91227	1425-1600	95	-14 TO 61	1-6
91228	1250-1600	190	-29 to 18	4-9

TABLE 4. Statistical Analysis Of Julian Date 91204

EMF	#08	#09	#12	#13	#16	#26	#28	#30
n	420	420	420	420	420	420	420	420
MEAN	370.3	359.9	362.1	464.4	560.2	584.7	590.1	413.6
MAX VALUE	654.9	615	3819	727.9	853	828.1	886	686.9
MIN VALUE	222.7	232.7	-3760	216.8	255.9	308.2	383.4	171.8
STD DEV	92.7	75.8	484.4	127.2	159.9	125.8	109.8	94.2

TABLE 5. Statistical Analysis Of Julian Date 91204 For Convergence And Sea Breeze Zones

EPM	#28 CONVERGENCE ZONE	#28 SEA BREEZE ZONE	#30 CONVERGENCE ZONE	#30 SEA BREEZE ZONE
N	41	56	46	56
MEAN	532.6	669.4	447.5	440.5
MAX VALUE	616.4	812.8	552.4	569.8
MIN VALUE	387.9	581.7	360.8	285.6
STD DEV	49.5	52.3	47.3	59.5

APPENDIX D

FIGURES

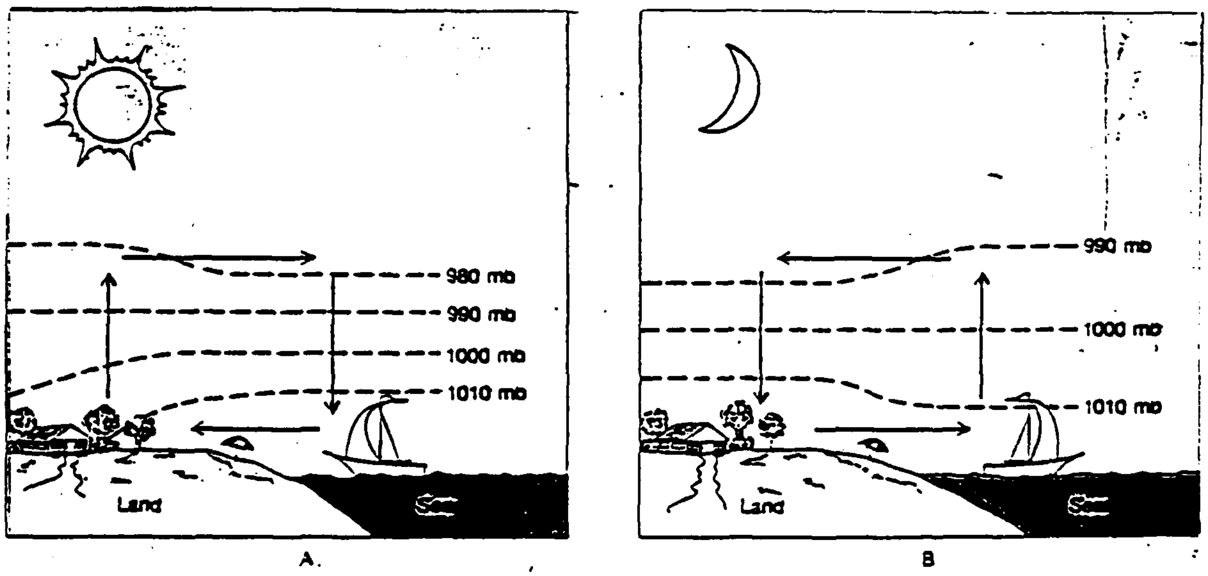

980 mb
990 mb
1000 mb
1010 mb
Land
Sea
A.
990 mb
1000 mb
1010 mb
Land
Sea
B

FIGURE 1

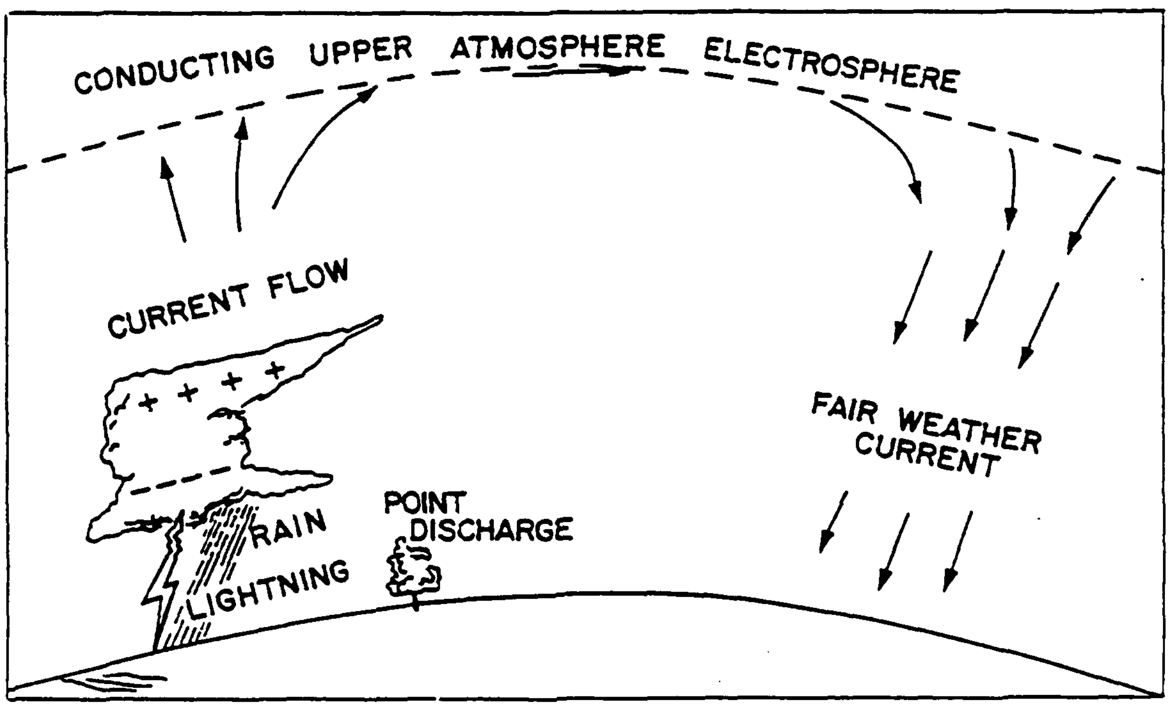
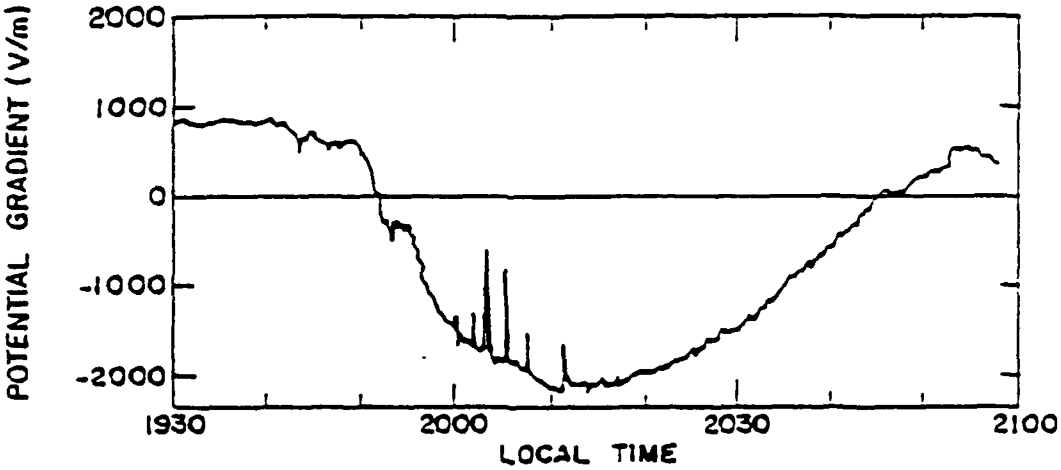

CONDUCTING UPPER ATMOSPHERE ELECTROSPHERE
CURRENT FLOW
FAIR WEATHER
CURRENT
POINT
DISCHARGE
RAIN
LIGHTNING

FIGURE 2



POTENTIAL GRADIENT (V/m)
2000
1000
0
-1000
-2000
1930
2000
2030
2100
LOCAL TIME

FIGURE 3

Eastern Range
CCAFS/KSC Meteorological Sensors

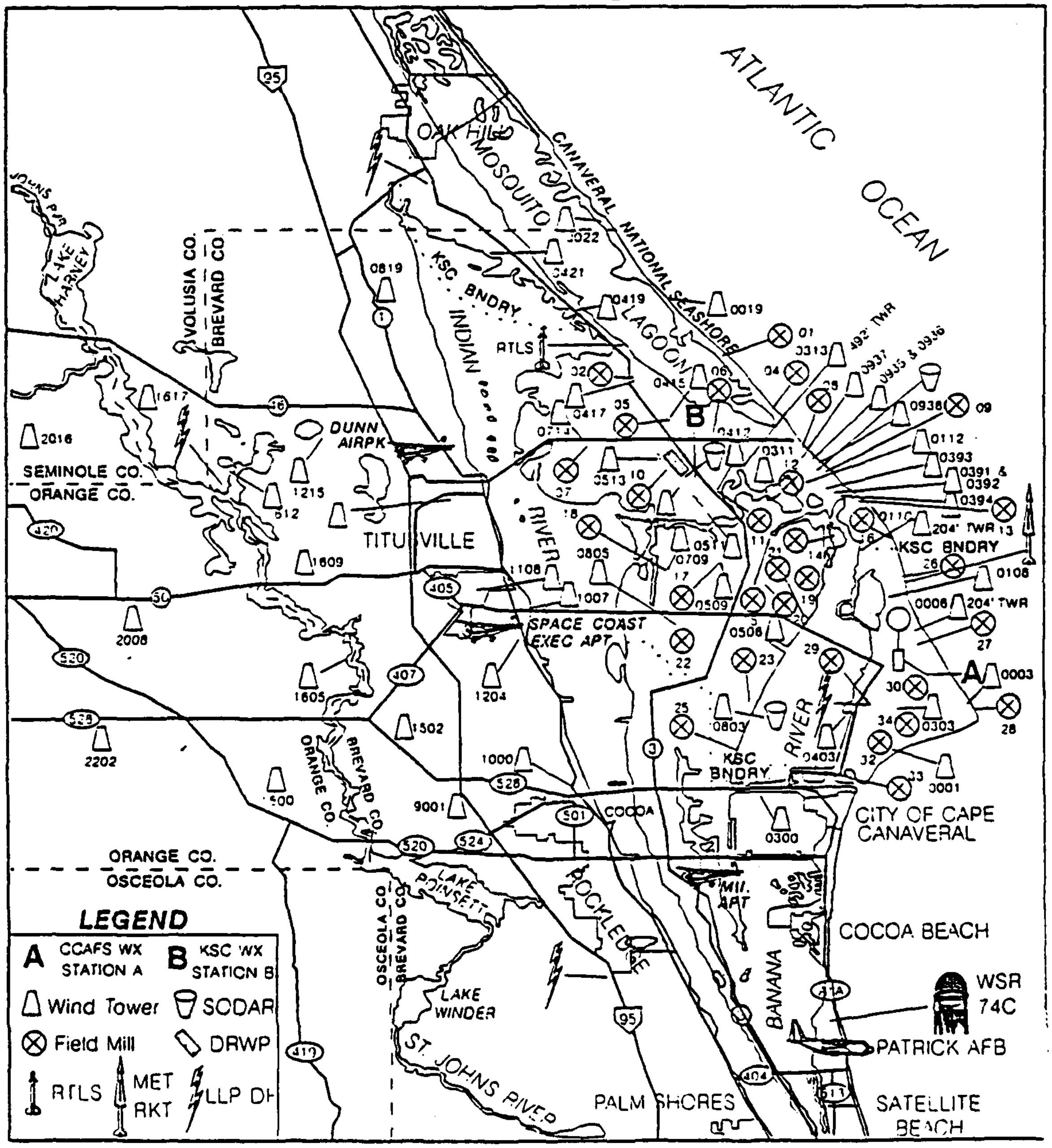


FIGURE 4

Eastern Range
CCAFS/KSC Wind Sensor Systems

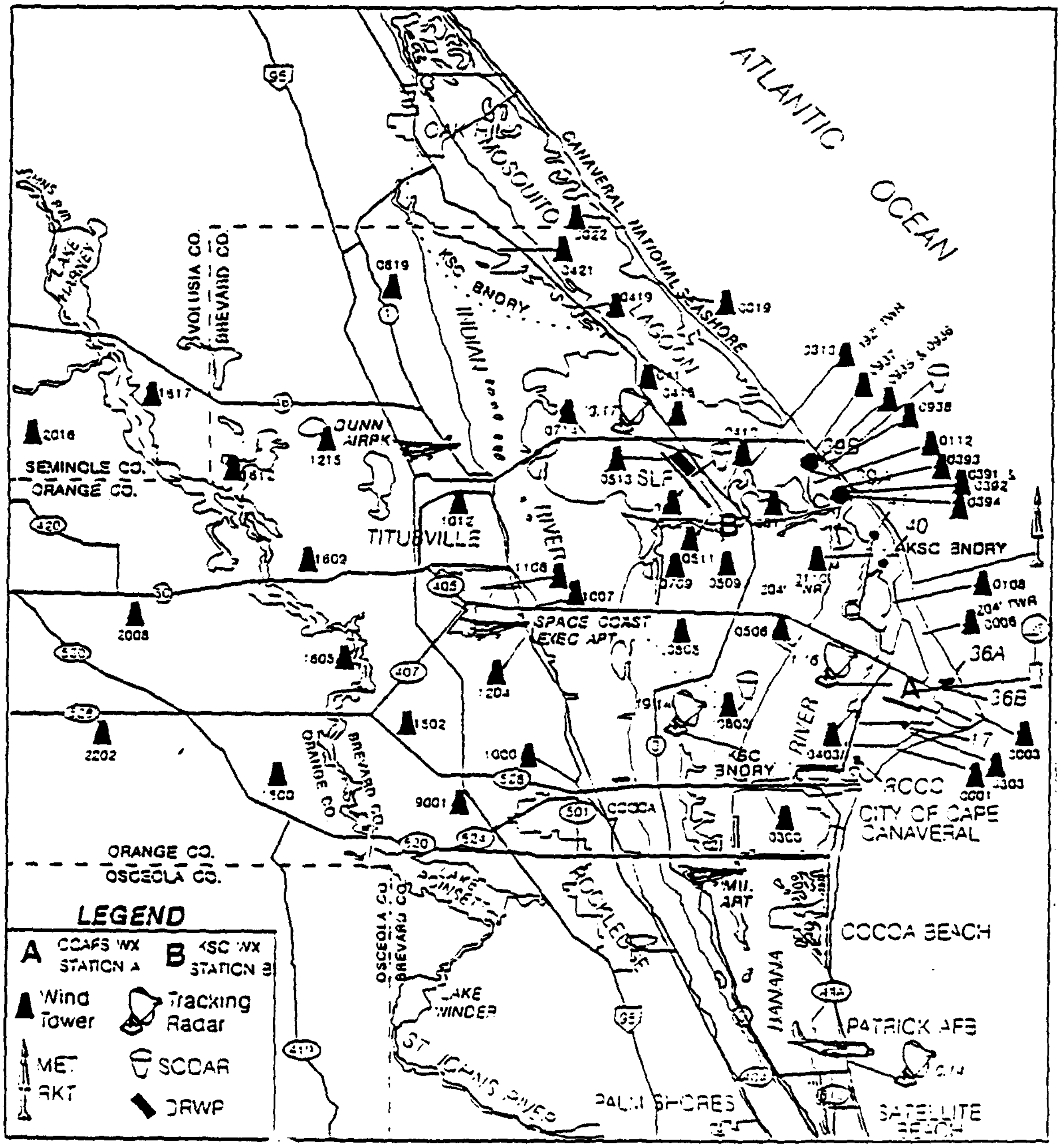


FIGURE 5

Eastern Range
CCAFS/KSC Atmospheric Electric Sensors

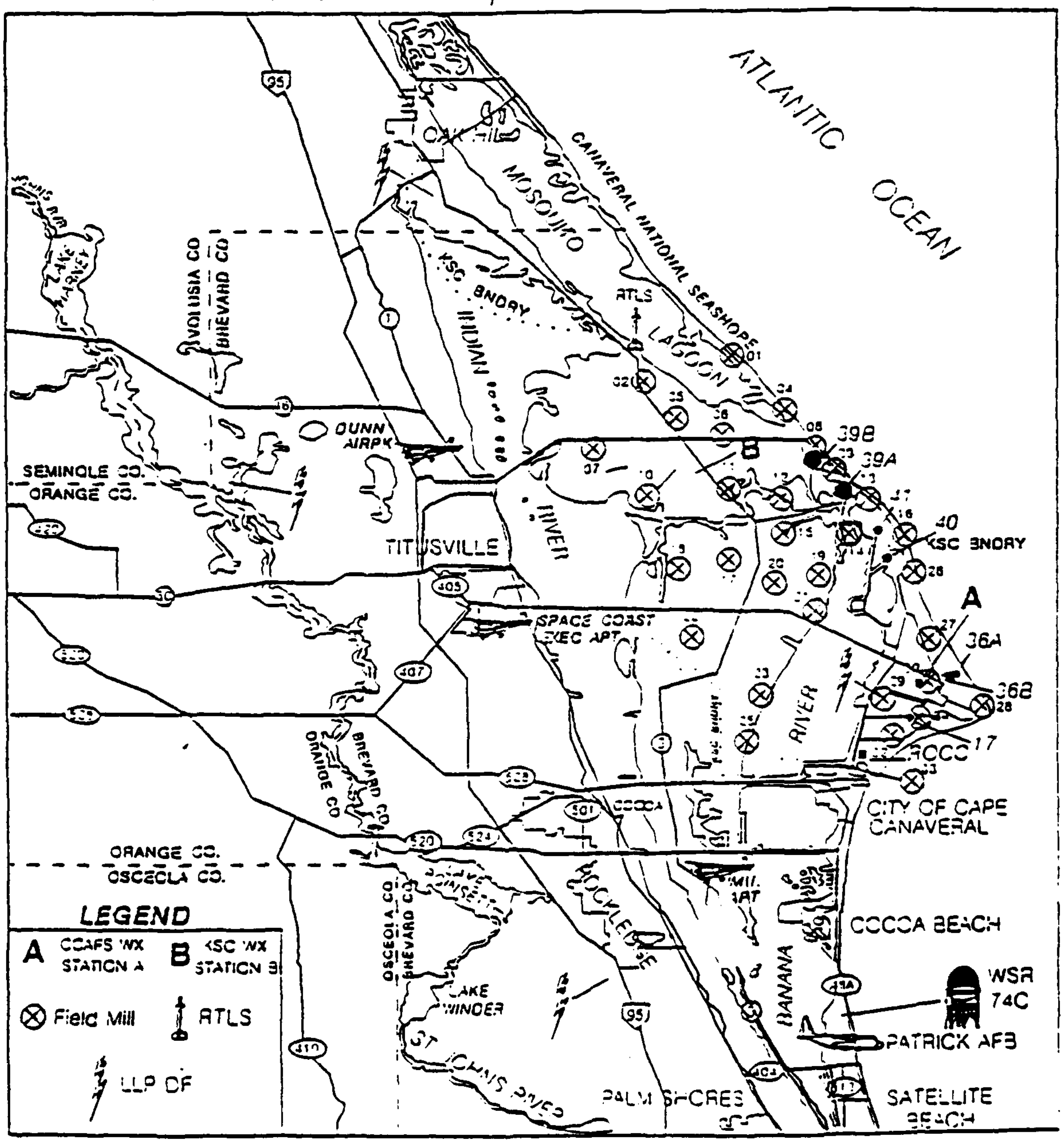


FIGURE 6

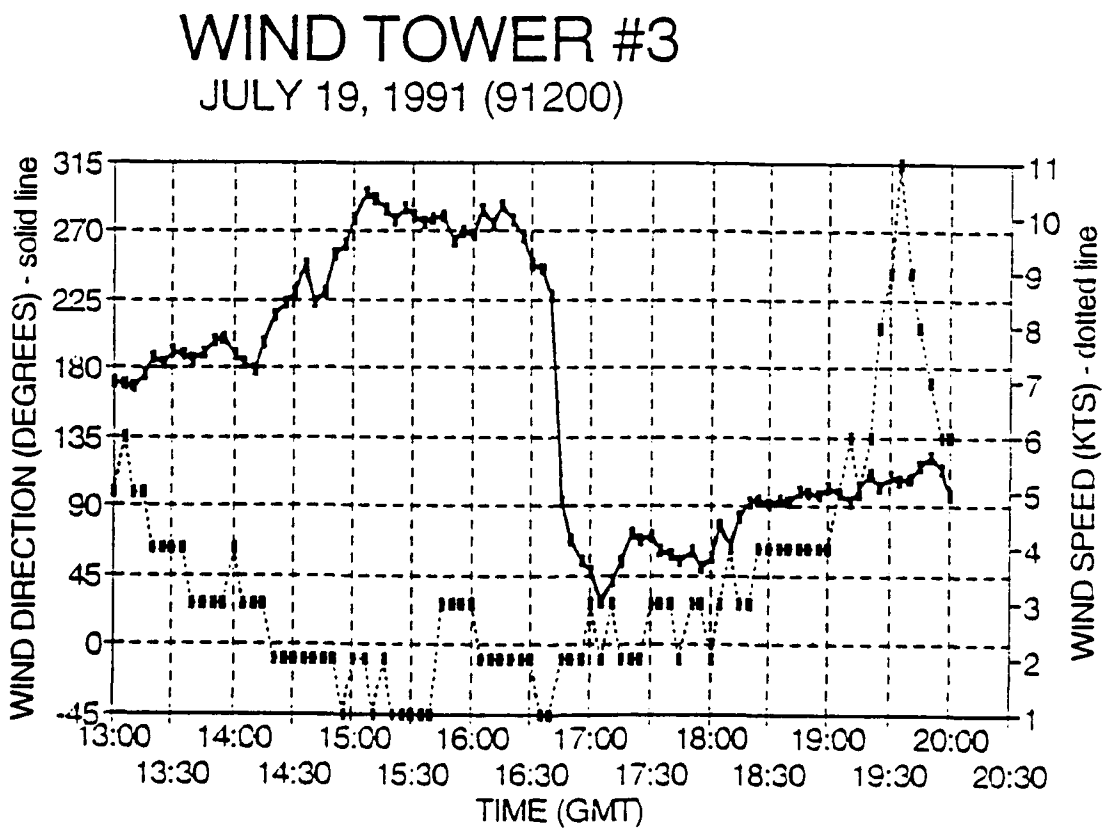

WIND TOWER #3
JULY 19, 1991 (91200)
WIND DIRECTION (DEGREES) - solid line
WIND SPEED (KTS) - dotted line
315
270
225
180
135
90
45
0
-45
11
10
9
8
7
6
5
4
3
2
1
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT)

FIGURE 7

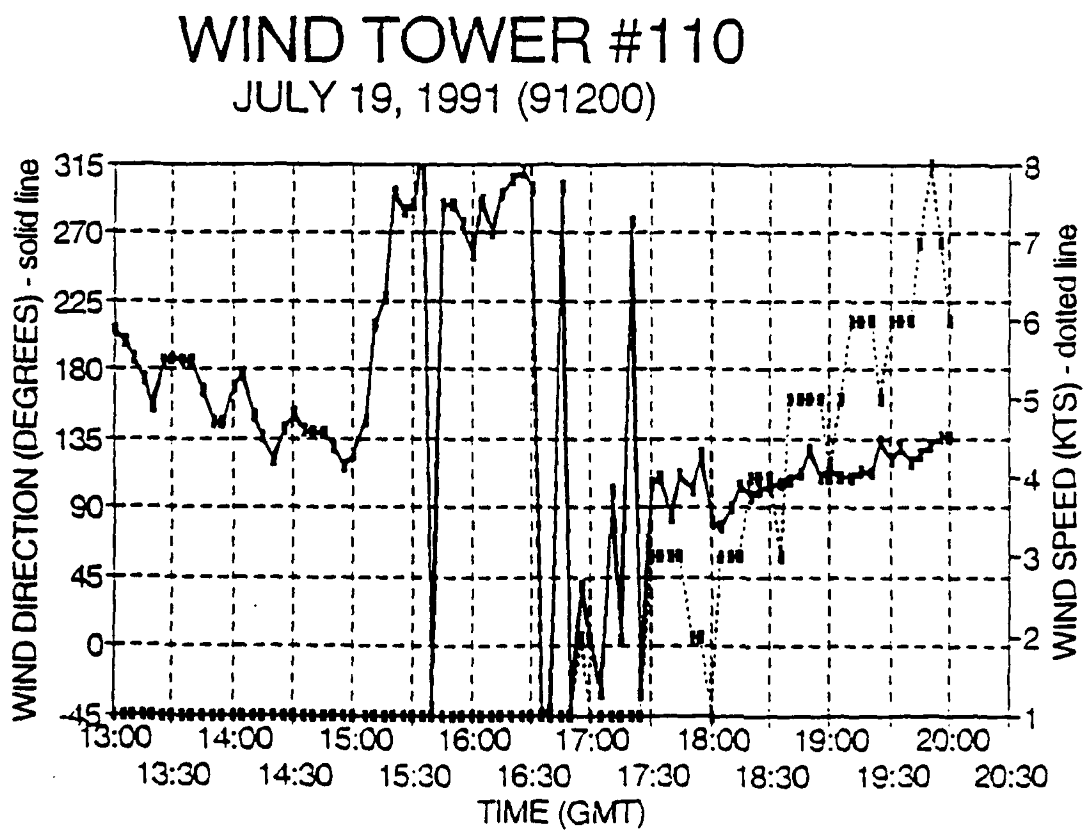

WIND TOWER #110
JULY 19, 1991 (91200)
WIND DIRECTION (DEGREES) - solid line
315
270
225
180
135
90
45
0
-45
WIND SPEED (KTS) - dotted line
8
7
6
5
4
3
2
1
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT)

FIGURE 8

WIND TOWER #112

JULY 19, 1991 (91200)

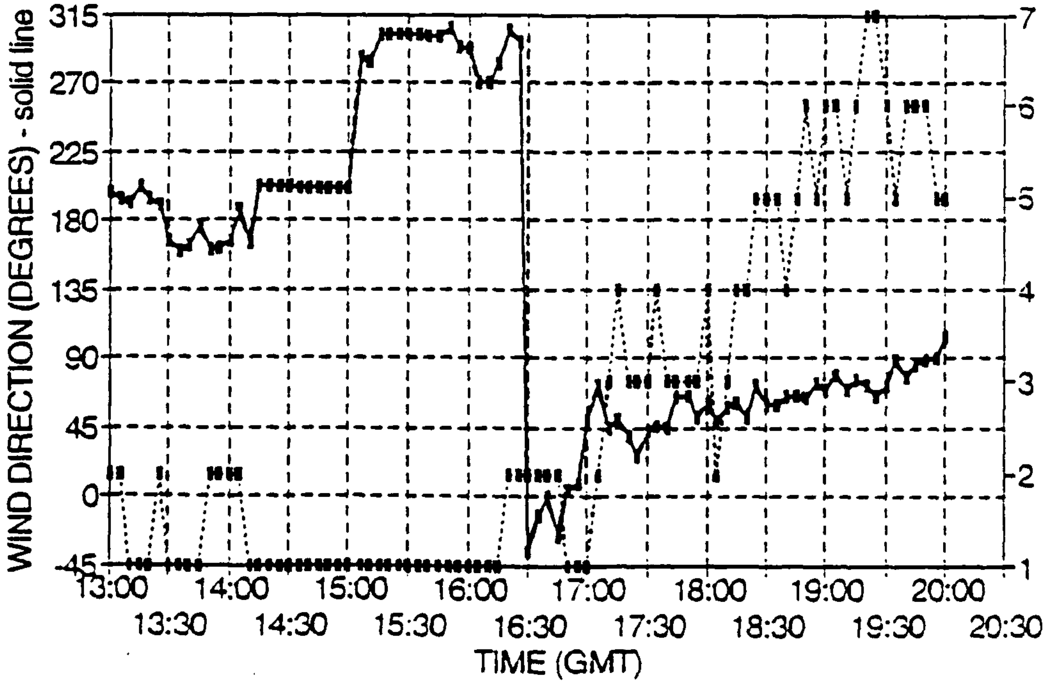


FIGURE 9

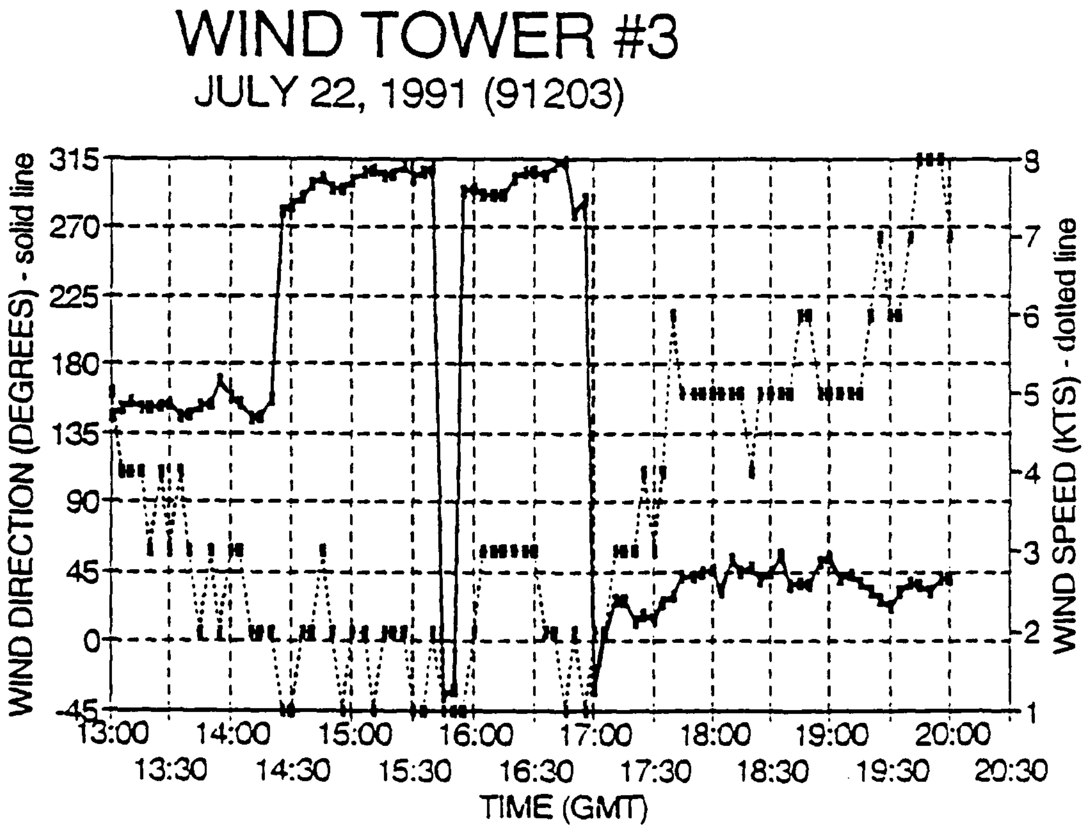

WIND TOWER #3
JULY 22, 1991 (91203)
WIND DIRECTION (DEGREES) - solid line
WIND SPEED (KTS) - dotted line
315
270
225
180
135
90
45
0
-45
8
7
6
5
4
3
2
1
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT)

FIGURE 10

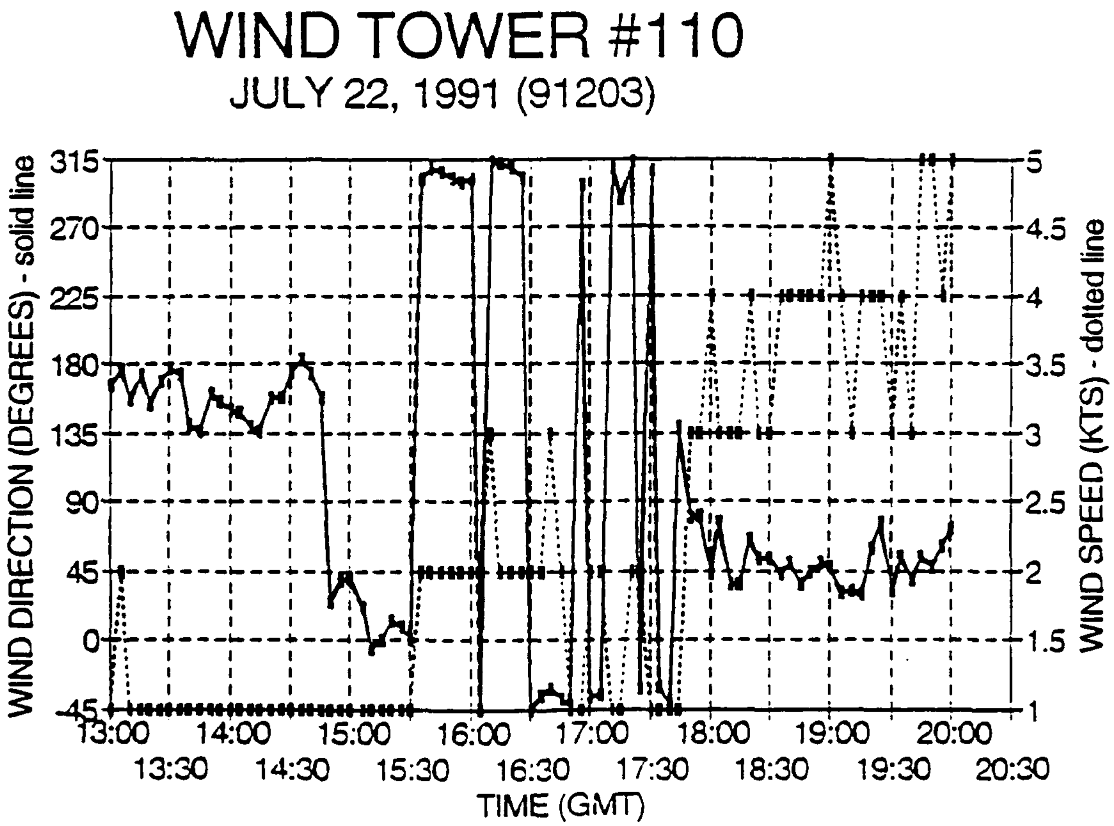
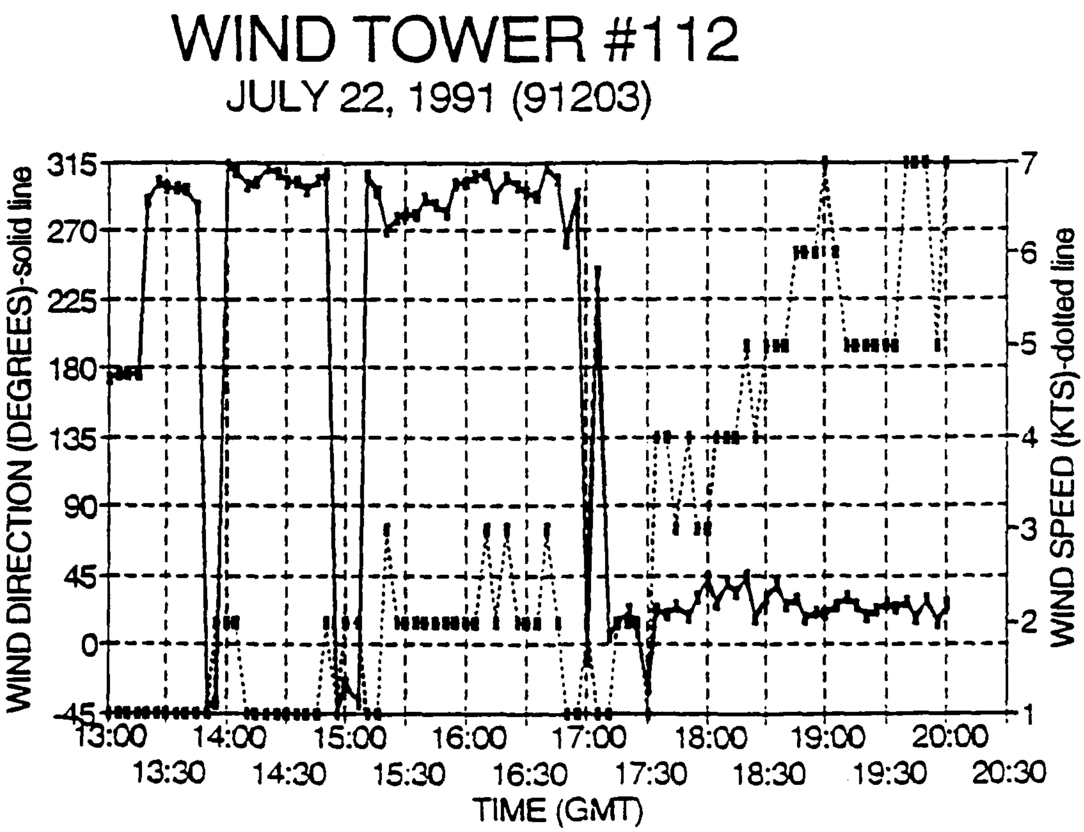

WIND TOWER #110
JULY 22, 1991 (91203)
WIND DIRECTION (DEGREES) - solid line
WIND SPEED (KTS) - dotted line
315
270
225
180
135
90
45
0
-45
5
4.5
4
3.5
3
2.5
2
1.5
1
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT)

FIGURE 11



WIND TOWER #112
JULY 22, 1991 (91203)
WIND DIRECTION (DEGREES)-solid line
WIND SPEED (KTS)-dotted line
315
270
225
180
135
90
45
0
-45
7
6
5
4
3
2
1
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT)

FIGURE 12

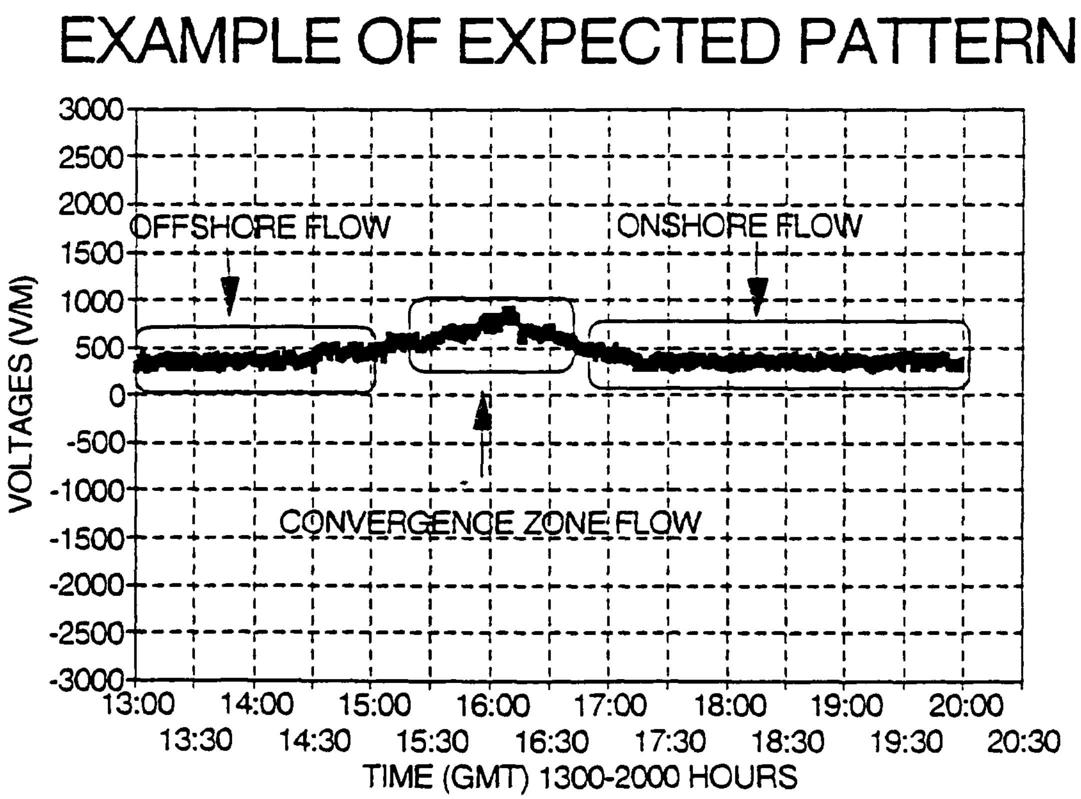

EXAMPLE OF EXPECTED PATTERN
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
OFFSHORE FLOW
ONSHORE FLOW
CONVERGENCE ZONE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 13

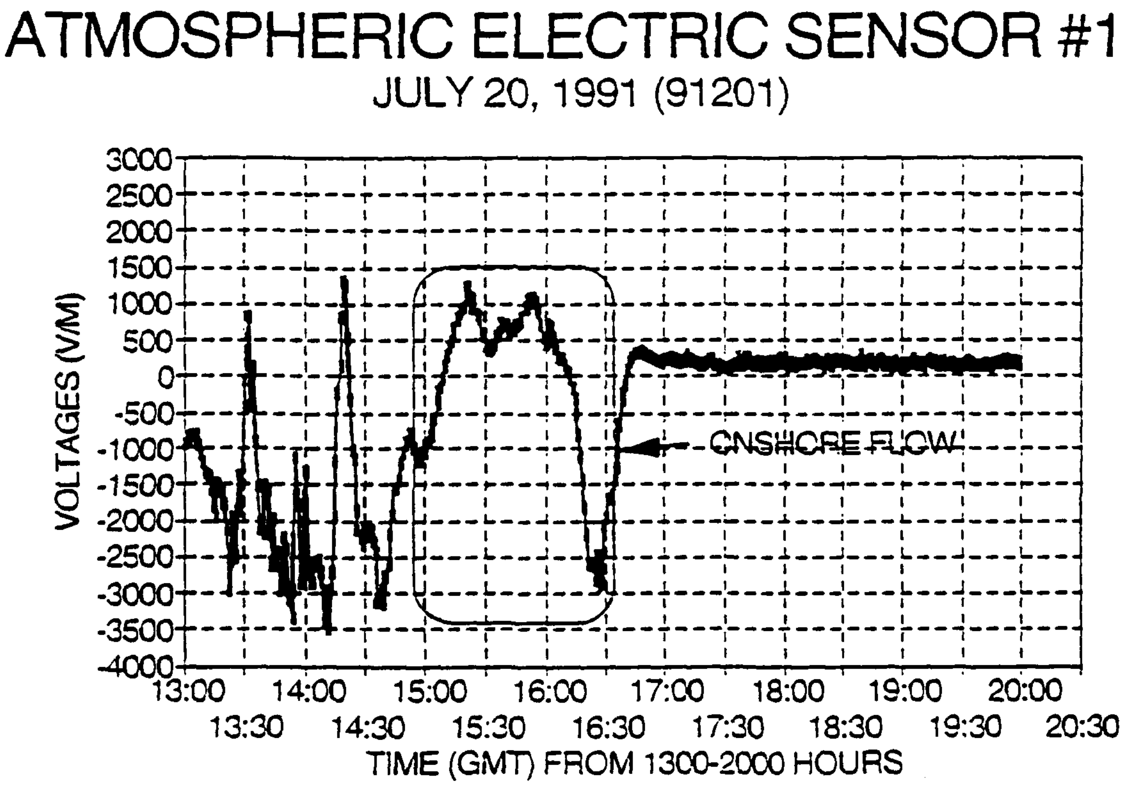

ATMOSPHERIC ELECTRIC SENSOR #13
JULY 20, 1991 (91201)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) FROM 1300-2000 HOURS
ONSHORE FLOW

FIGURE 14

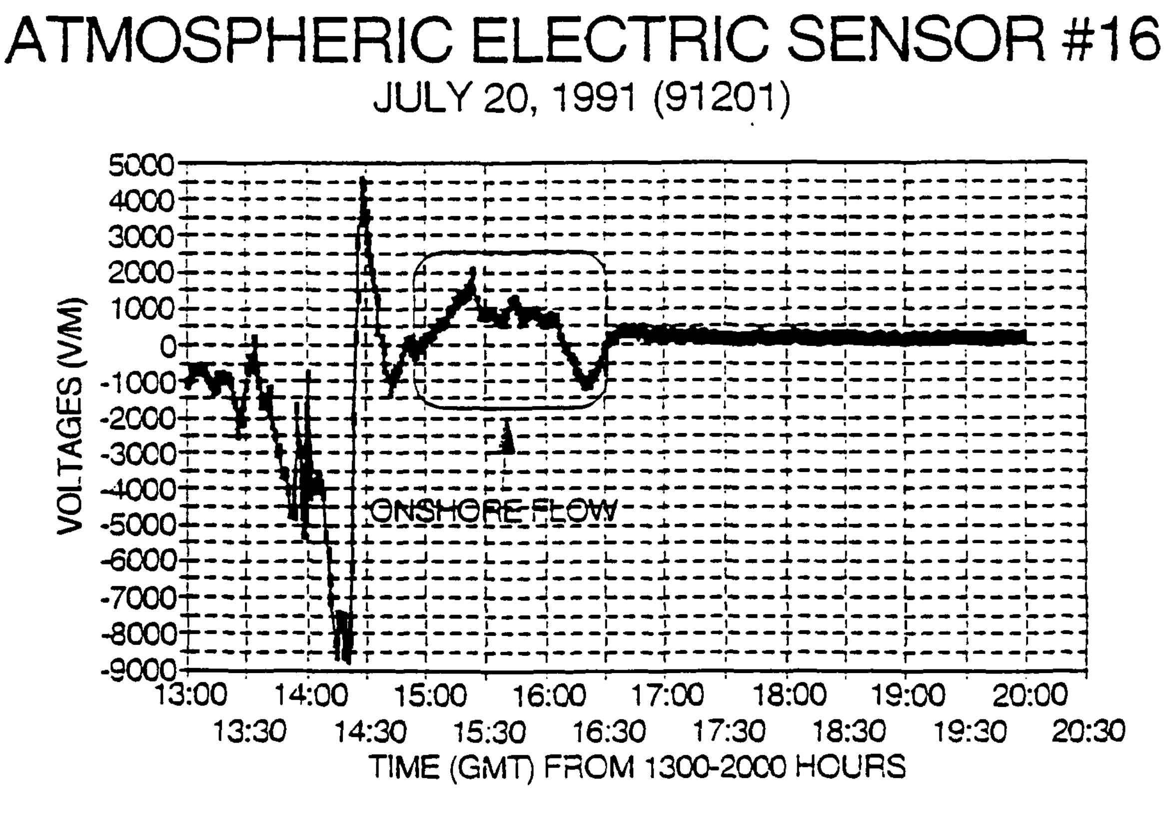
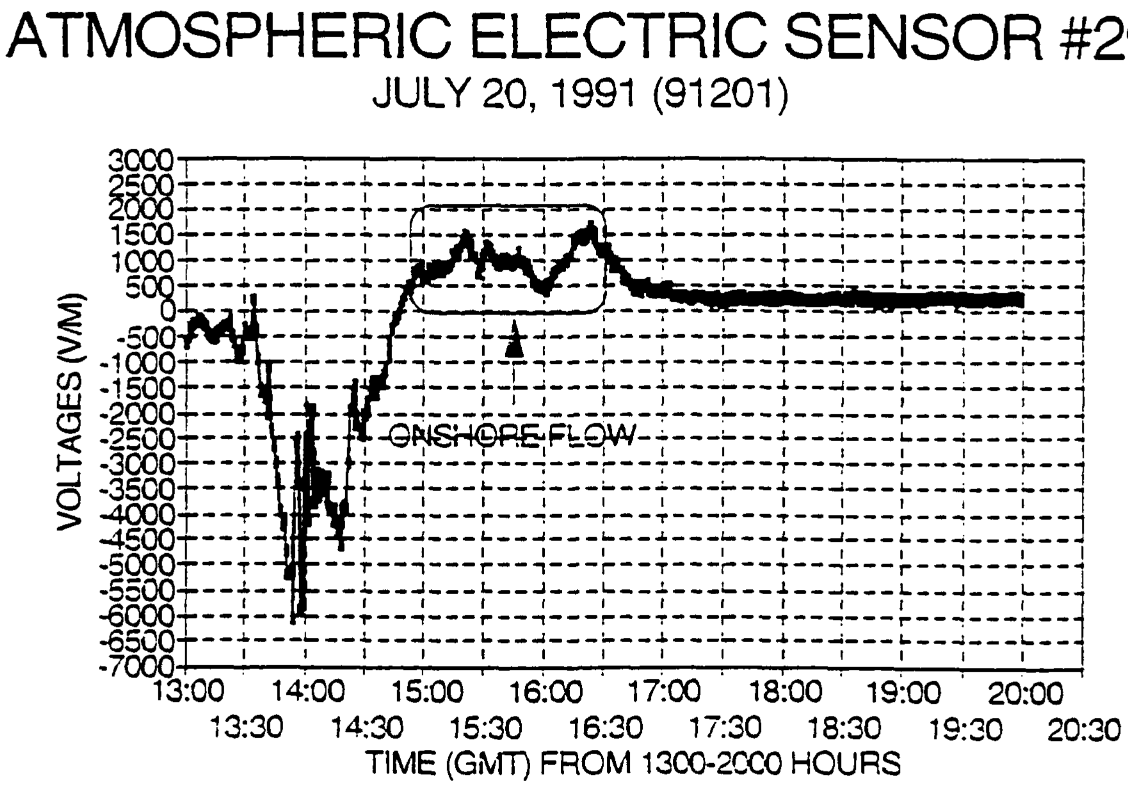

ATMOSPHERIC ELECTRIC SENSOR #16
JULY 20, 1991 (91201)
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) FROM 1300-2000 HOURS

FIGURE 15



ATMOSPHERIC ELECTRIC SENSOR #26
JULY 20, 1991 (91201)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
-6500
-7000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) FROM 1300-2000 HOURS

FIGURE 16

ATMOSPHERIC ELECTRIC SENSOR #28

JULY 20, 1991 (91201)

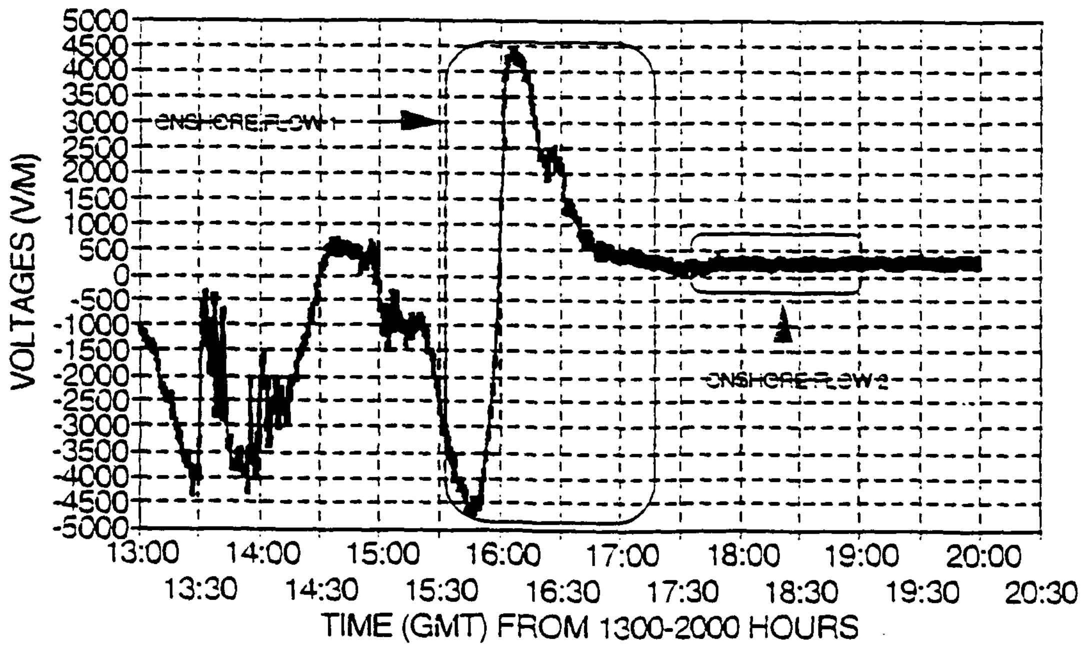


FIGURE 17

ATMOSPHERIC ELECTRIC SENSOR #30

JULY 20, 1991 (91201)

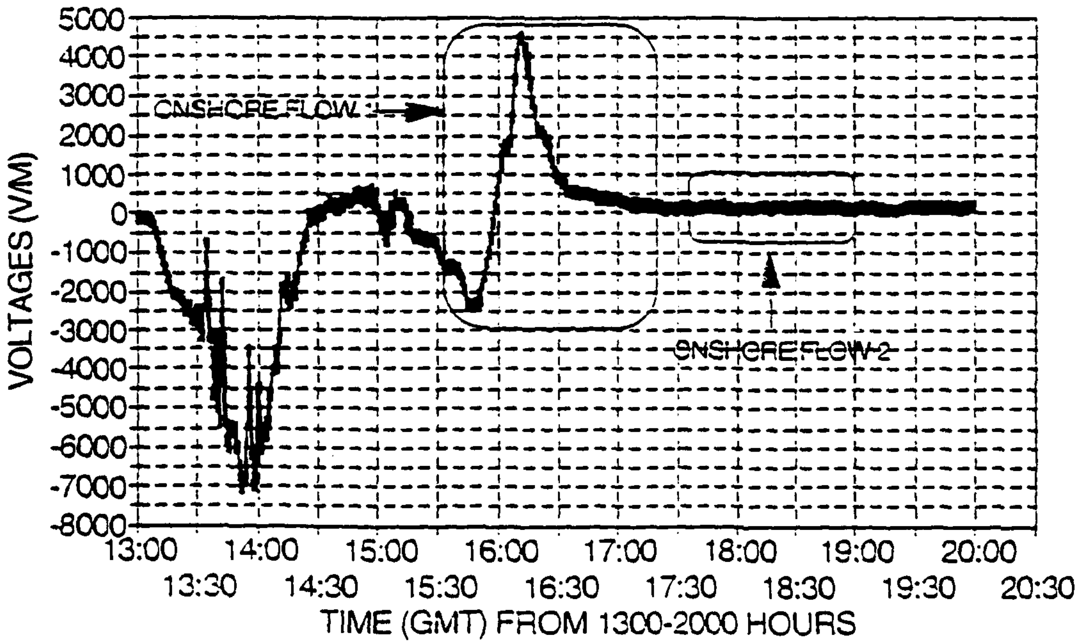


FIGURE 18

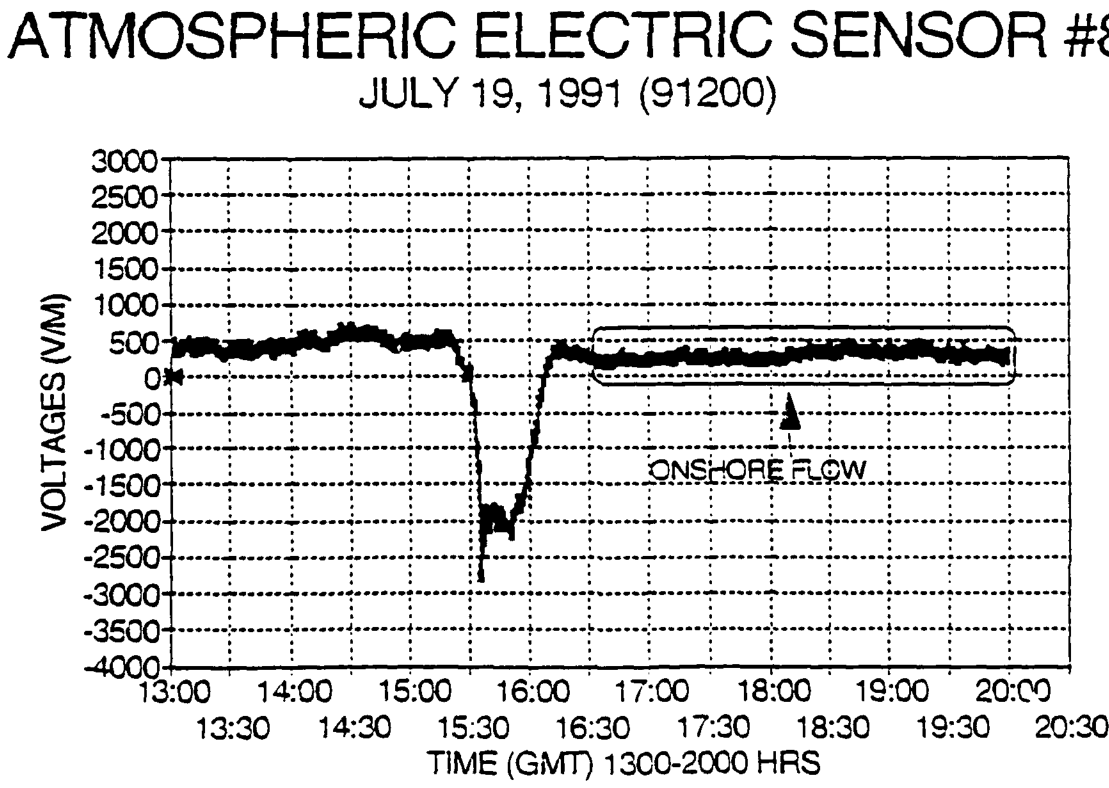

ATMOSPHERIC ELECTRIC SENSOR #8
JULY 19, 1991 (91200)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HRS

FIGURE 19

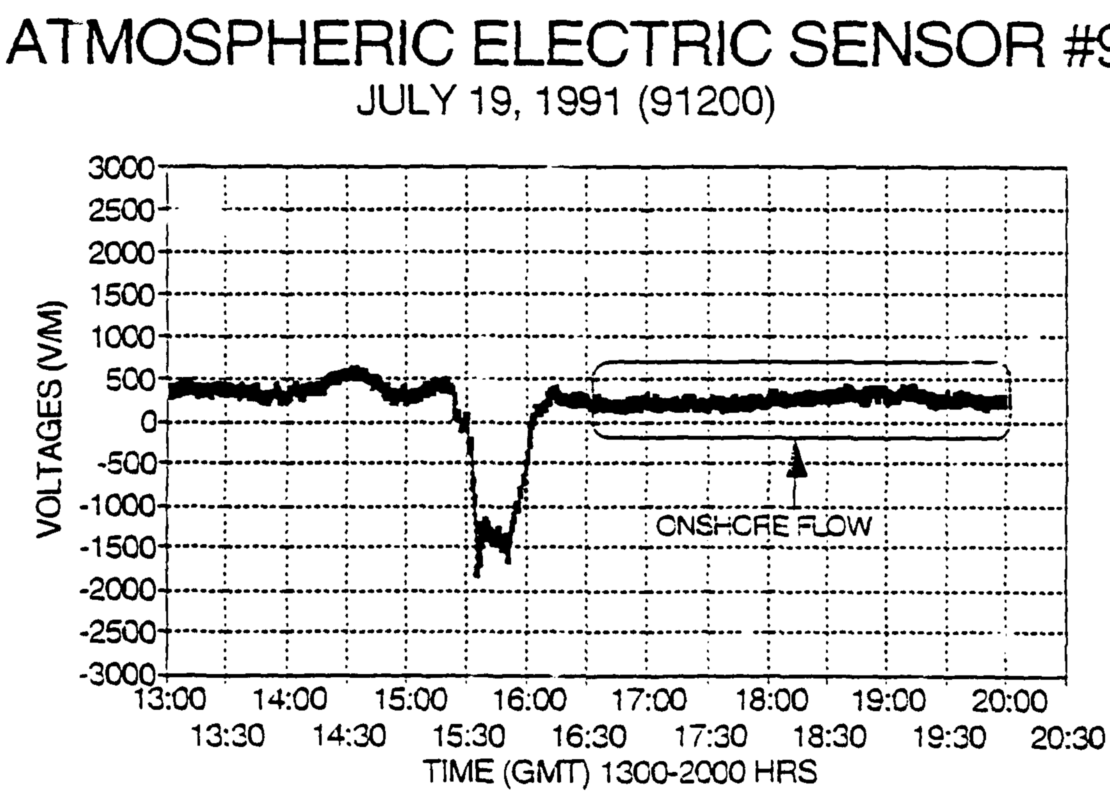

ATMOSPHERIC ELECTRIC SENSOR #9
JULY 19, 1991 (91200)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HRS

FIGURE 20

ATMOSPHERIC ELECTRIC SENSOR #12

JULY 19, 1991 (91200)

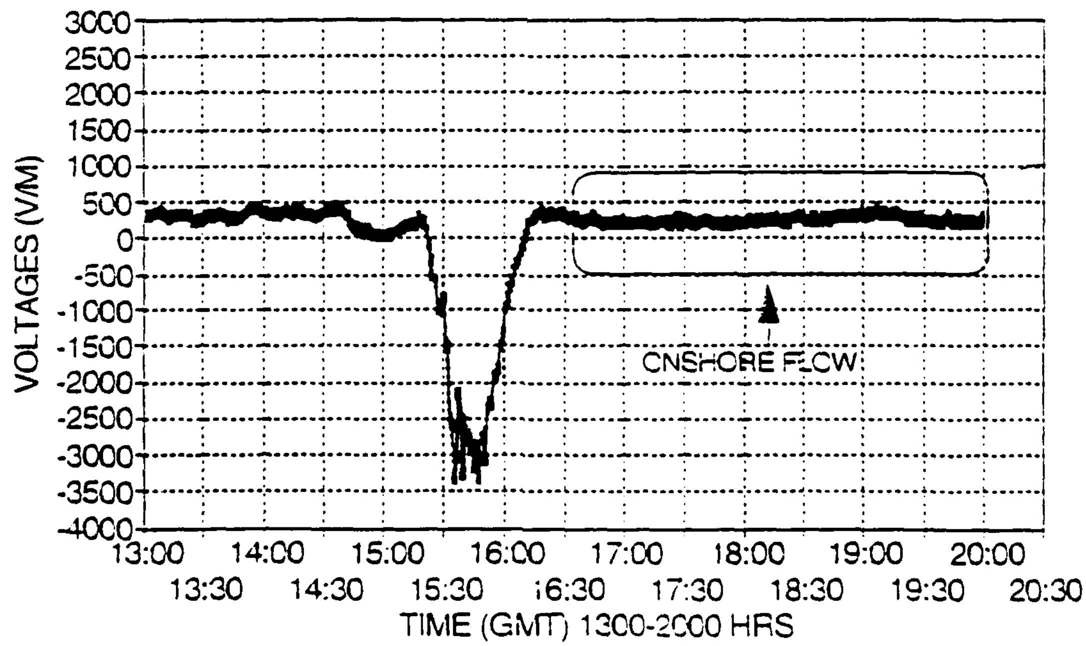


FIGURE 21

ATMOSPHERIC ELECTRIC SENSOR #13

JULY 19, 1991 (91200)

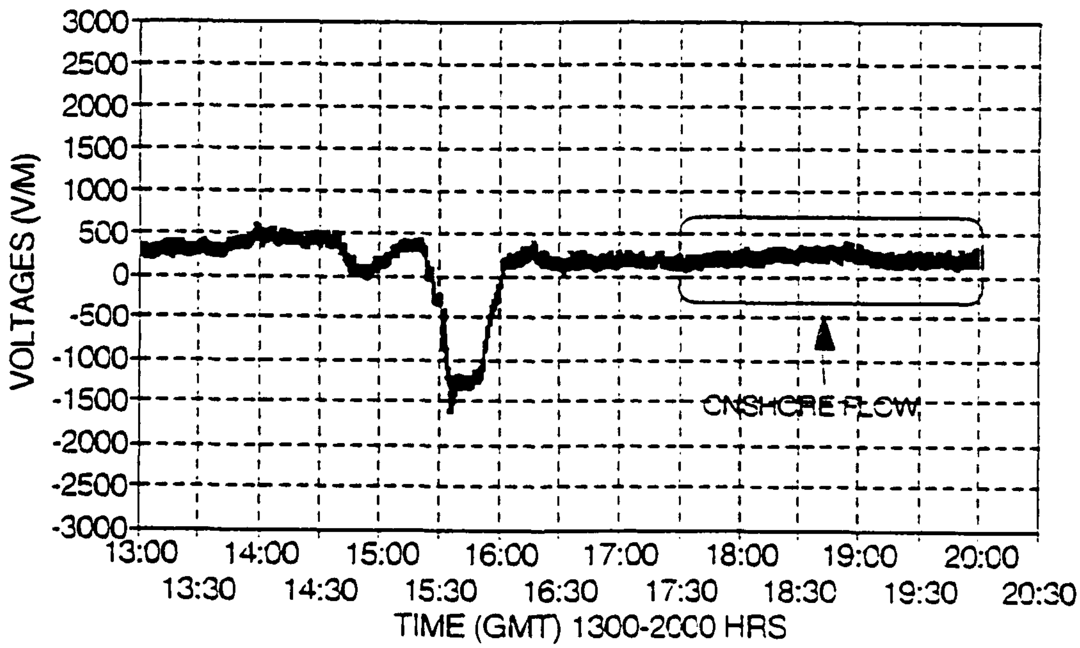


FIGURE 22

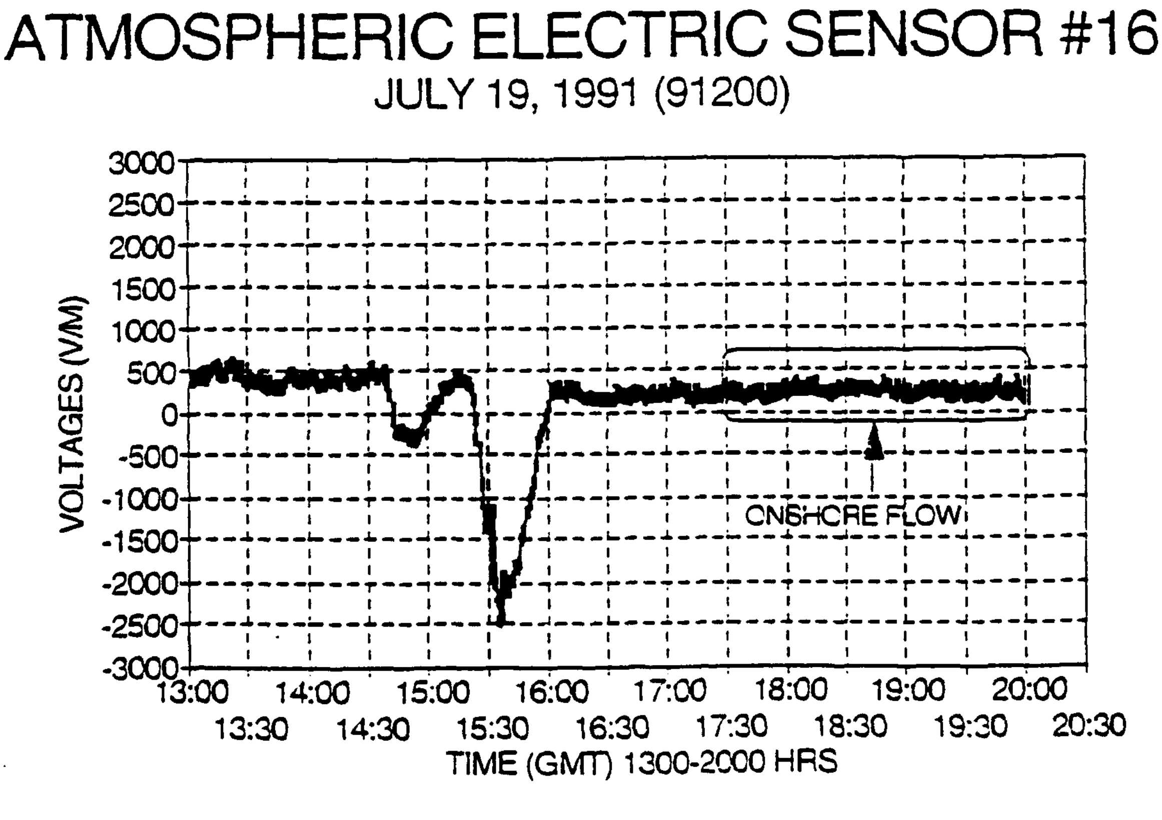

ATMOSPHERIC ELECTRIC SENSOR #16
JULY 19, 1991 (91200)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HRS

FIGURE 23

ATMOSPHERIC ELECTRIC SENSOR #26

JULY 19, 1991 (91200)

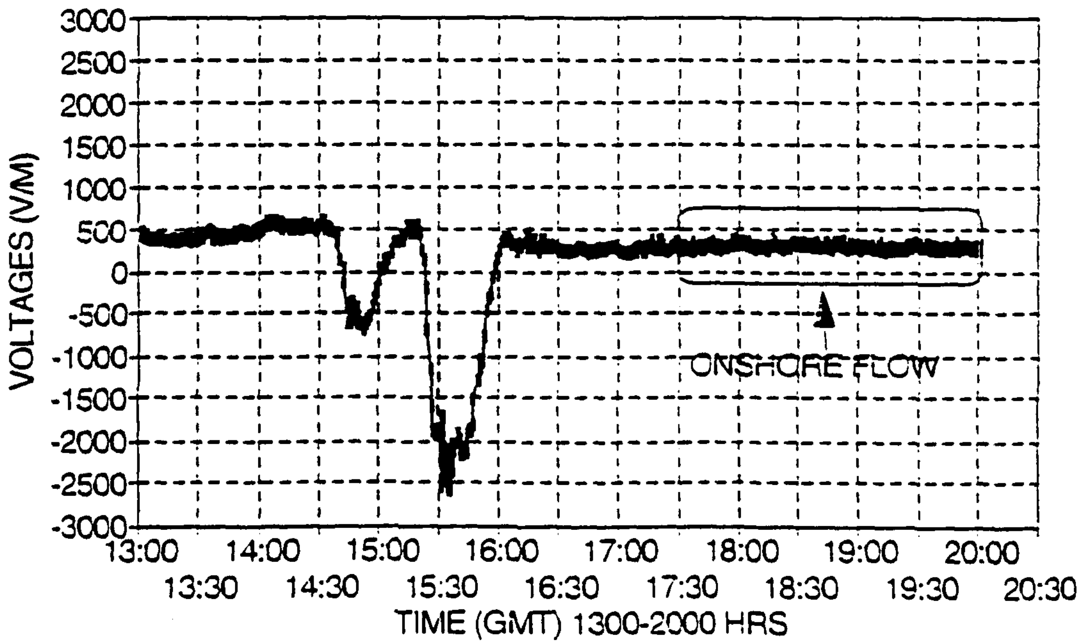


FIGURE 24

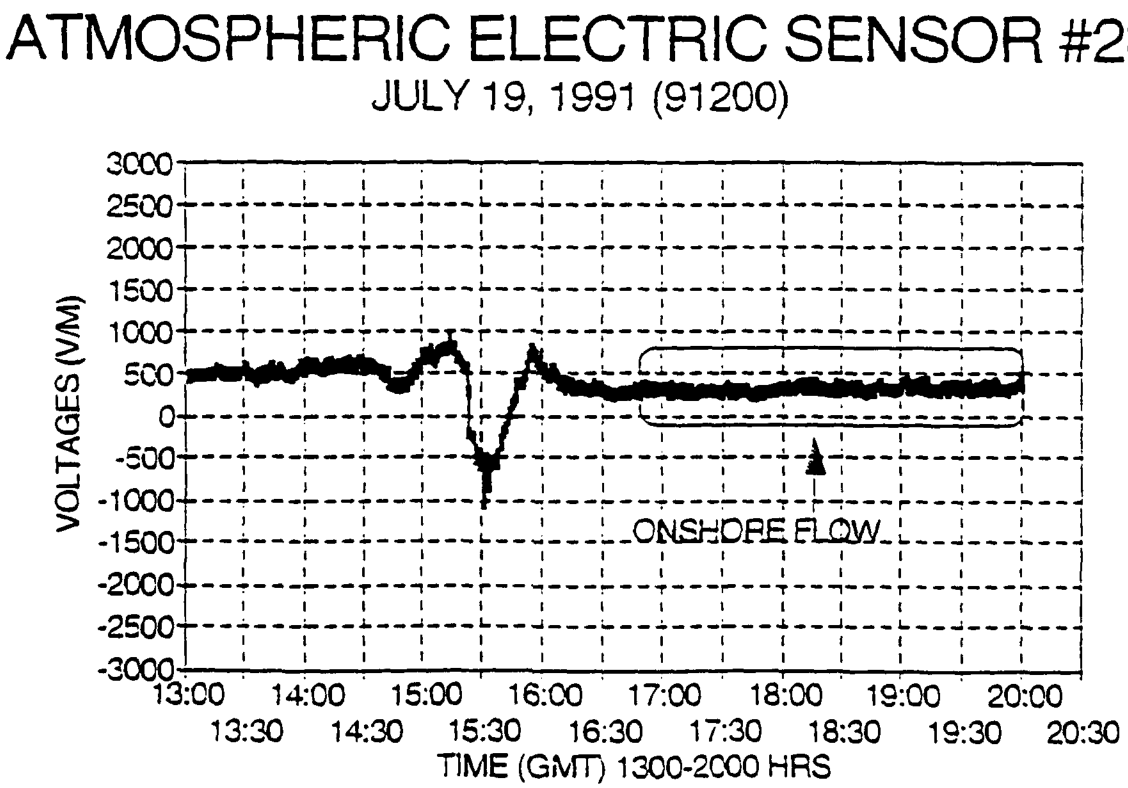

ATMOSPHERIC ELECTRIC SENSOR #28
JULY 19, 1991 (91200)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HRS

FIGURE 25

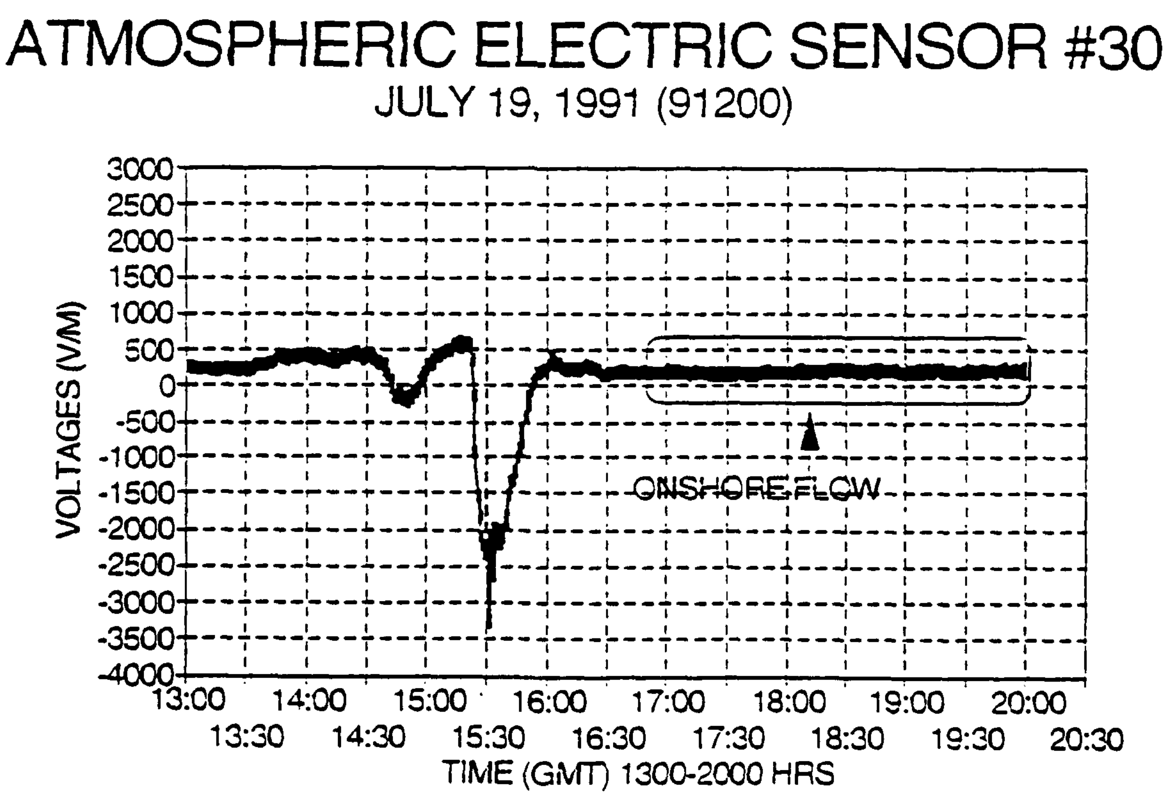
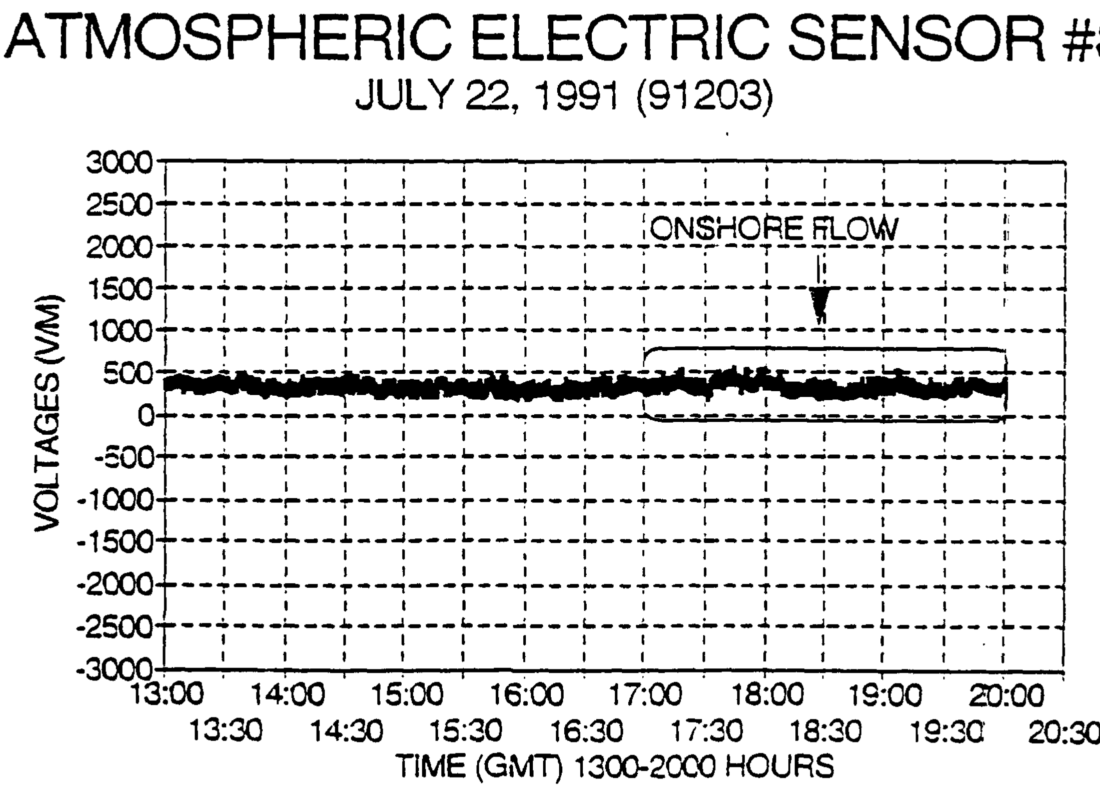

ATMOSPHERIC ELECTRIC SENSOR #30
JULY 19, 1991 (91200)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HRS

FIGURE 26



ATMOSPHERIC ELECTRIC SENSOR #8
JULY 22, 1991 (91203)
ONSHORE FLOW
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00
13:30 14:30 15:30 16:30 17:30 18:30 19:30 20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 27

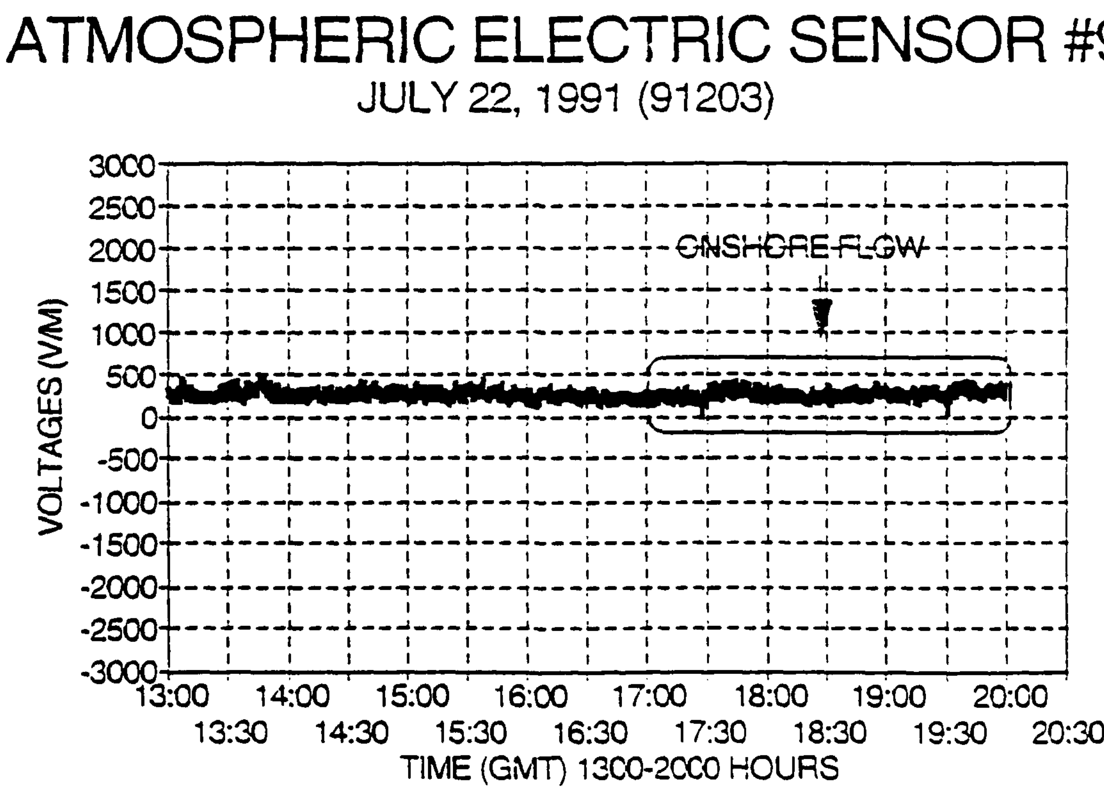

ATMOSPHERIC ELECTRIC SENSOR #9
JULY 22, 1991 (91203)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 28

ATMOSPHERIC ELECTRIC SENSOR #12

JULY 22, 1991 (91203)

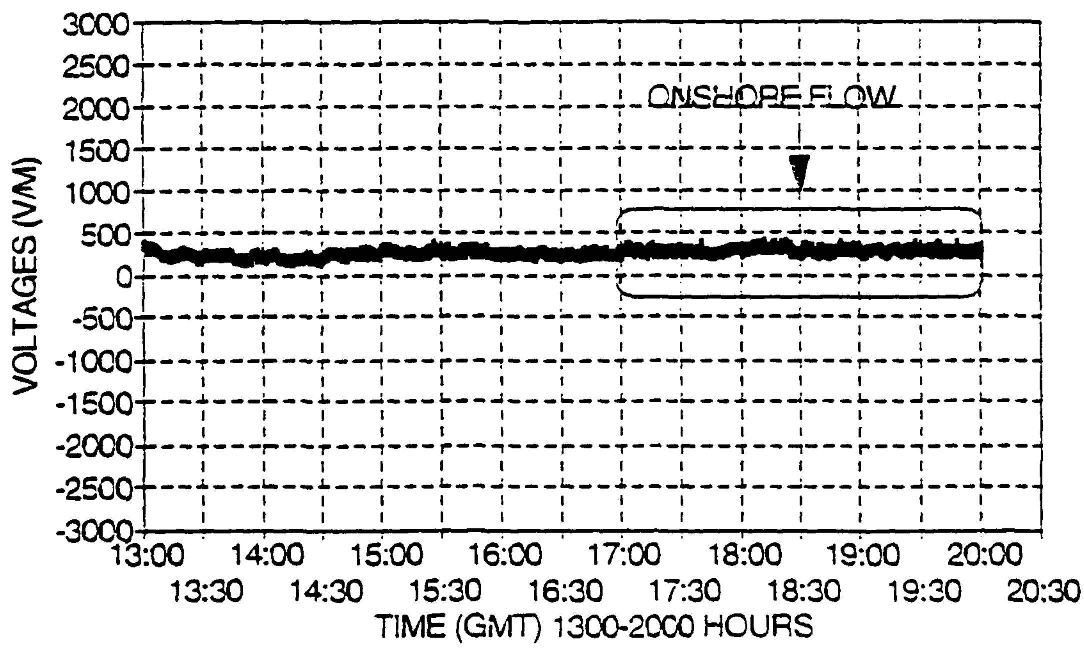


FIGURE 29

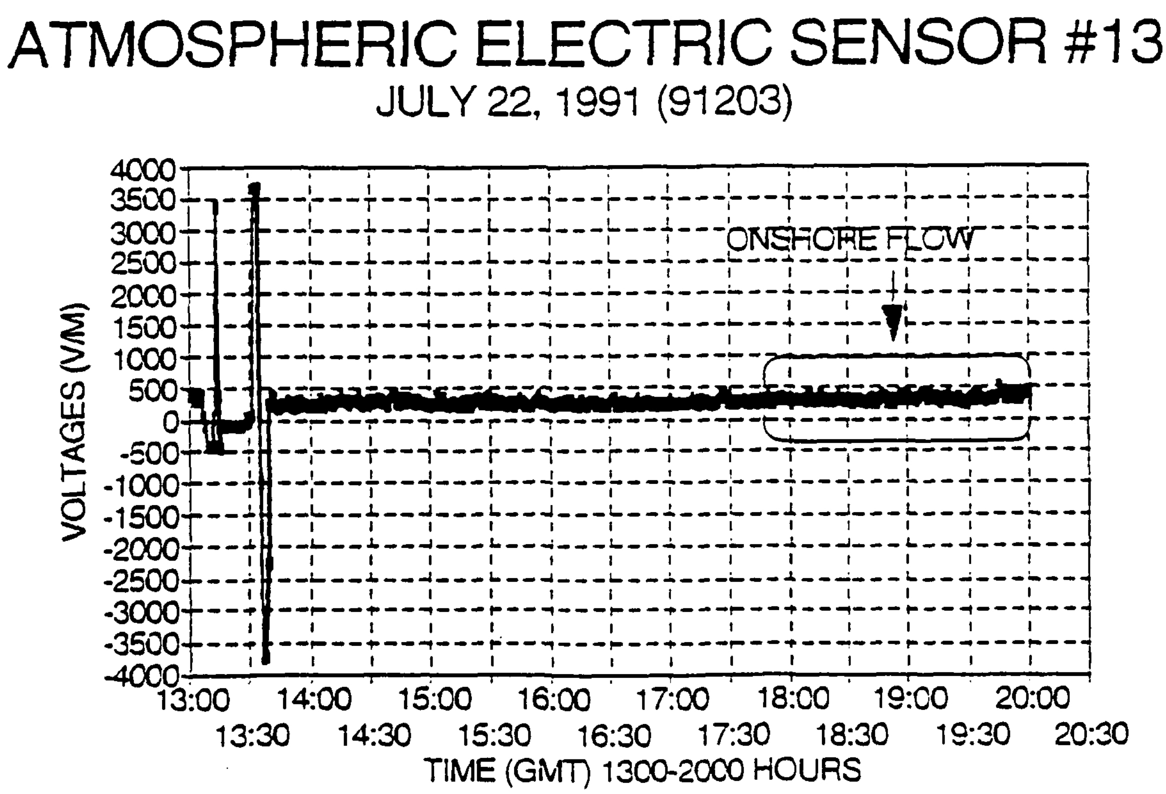
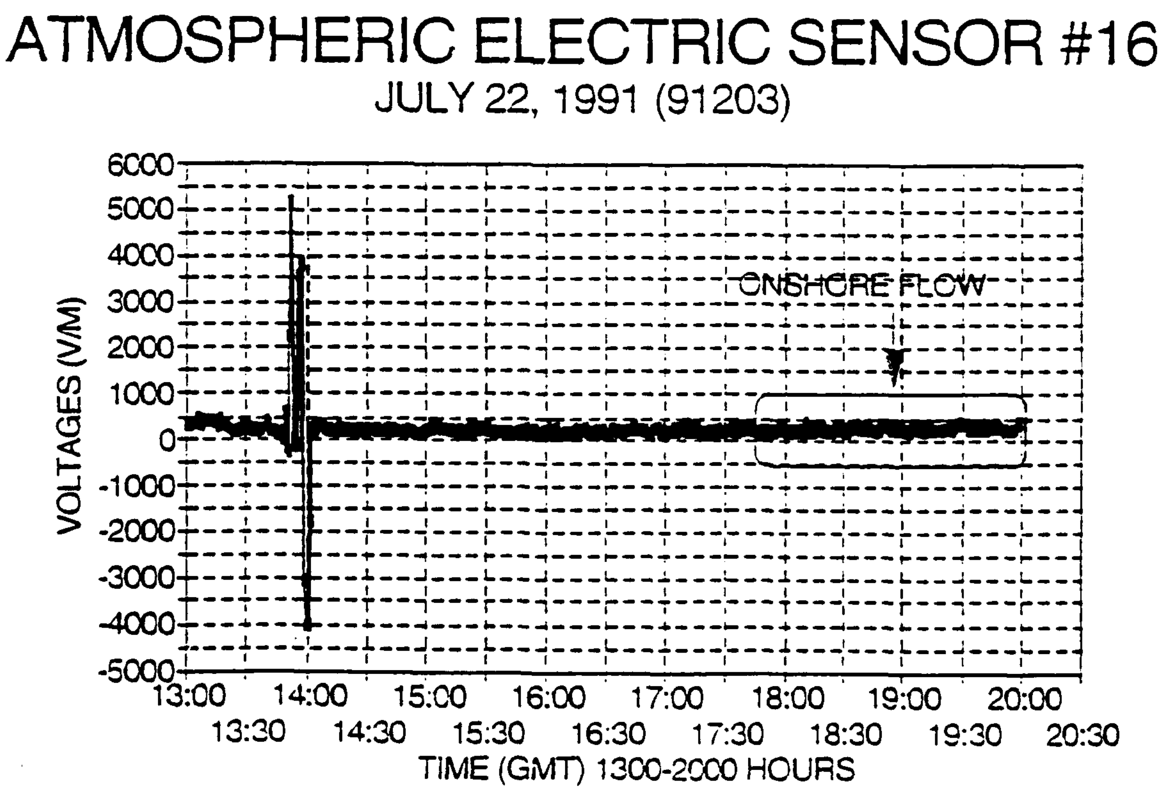

ATMOSPHERIC ELECTRIC SENSOR #13
JULY 22, 1991 (91203)
ONSHORE FLOW
VOLTAGES (V/M)
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 30



ATMOSPHERIC ELECTRIC SENSOR #16
JULY 22, 1991 (91203)
VOLTAGES (V/M)
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 31

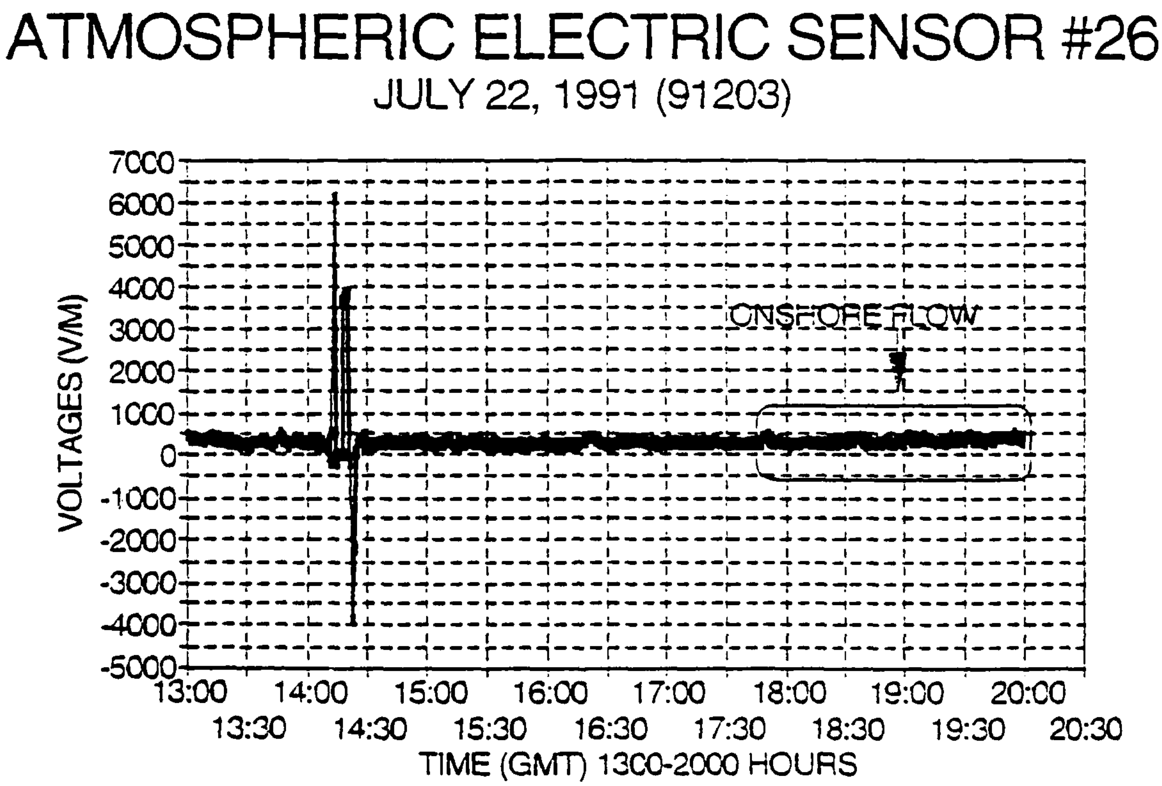

ATMOSPHERIC ELECTRIC SENSOR #26
JULY 22, 1991 (91203)
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 32

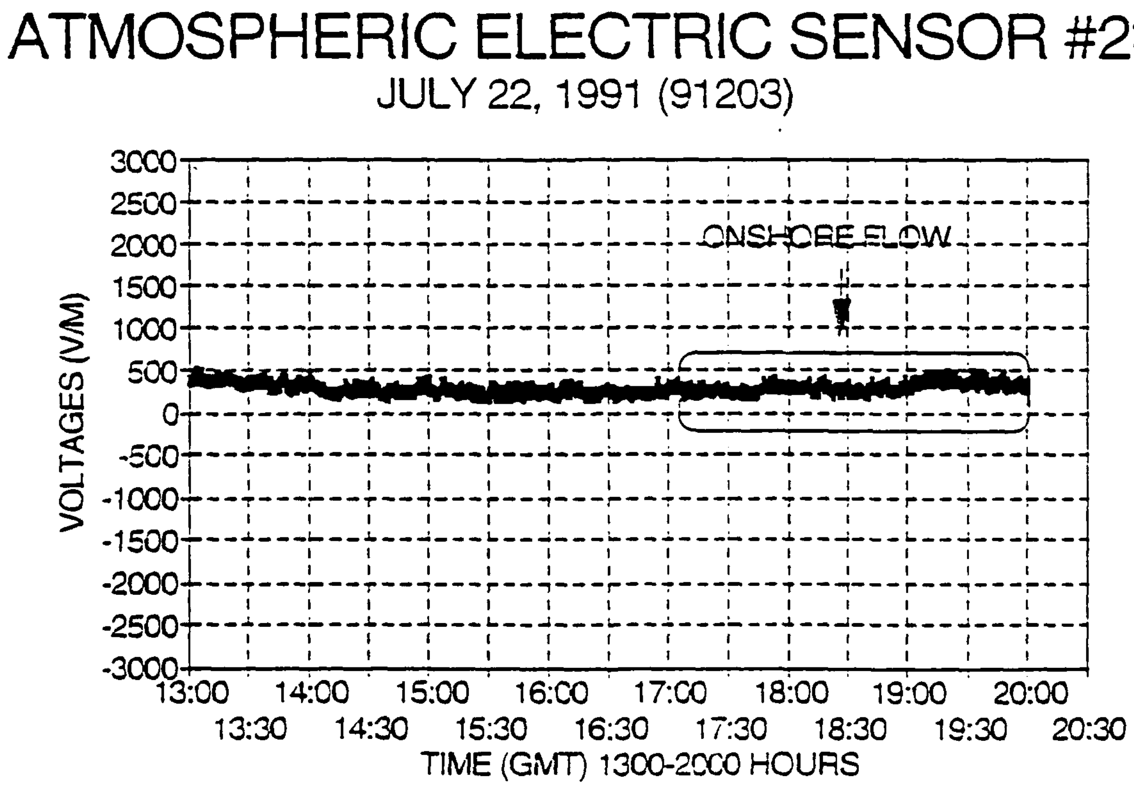

ATMOSPHERIC ELECTRIC SENSOR #28
JULY 22, 1991 (91203)
ONSHORE FLOW
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00
13:30 14:30 15:30 16:30 17:30 18:30 19:30 20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 33

ATMOSPHERIC ELECTRIC SENSOR #30

JULY 22, 1991 (91203)

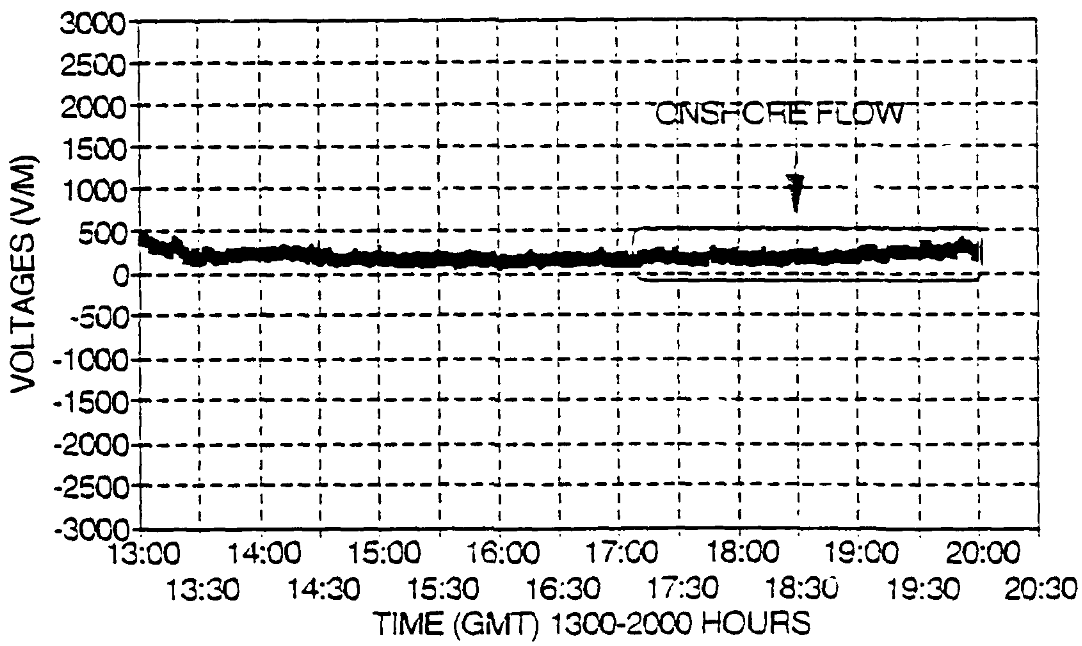


FIGURE 34

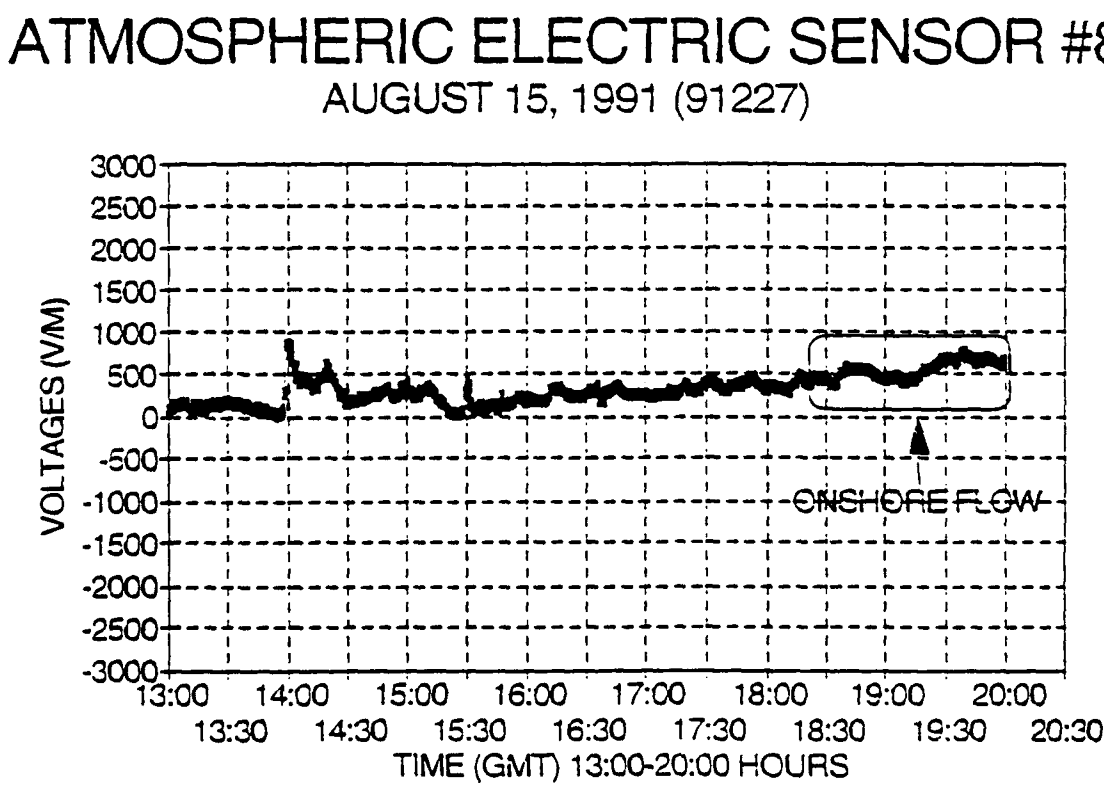

ATMOSPHERIC ELECTRIC SENSOR #8
AUGUST 15, 1991 (91227)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS
ONSHORE FLOW

FIGURE 35

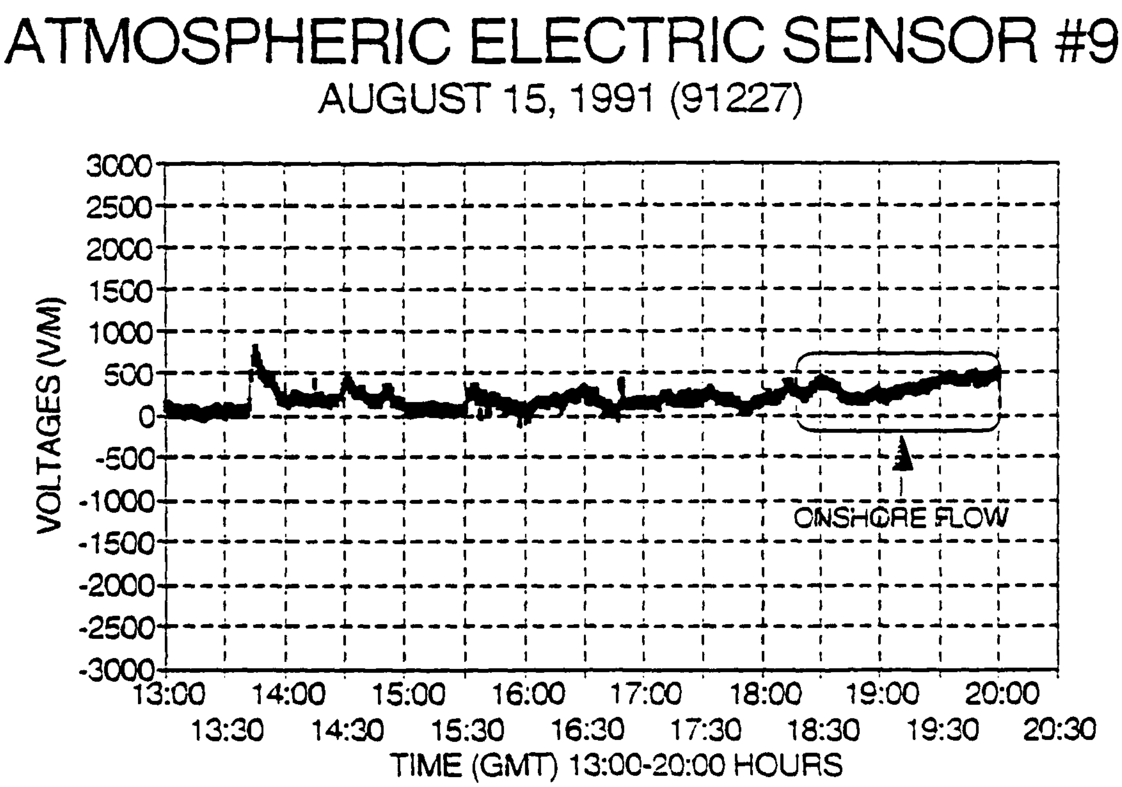

ATMOSPHERIC ELECTRIC SENSOR #9
AUGUST 15, 1991 (91227)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS
ONSHORE FLOW

FIGURE 36

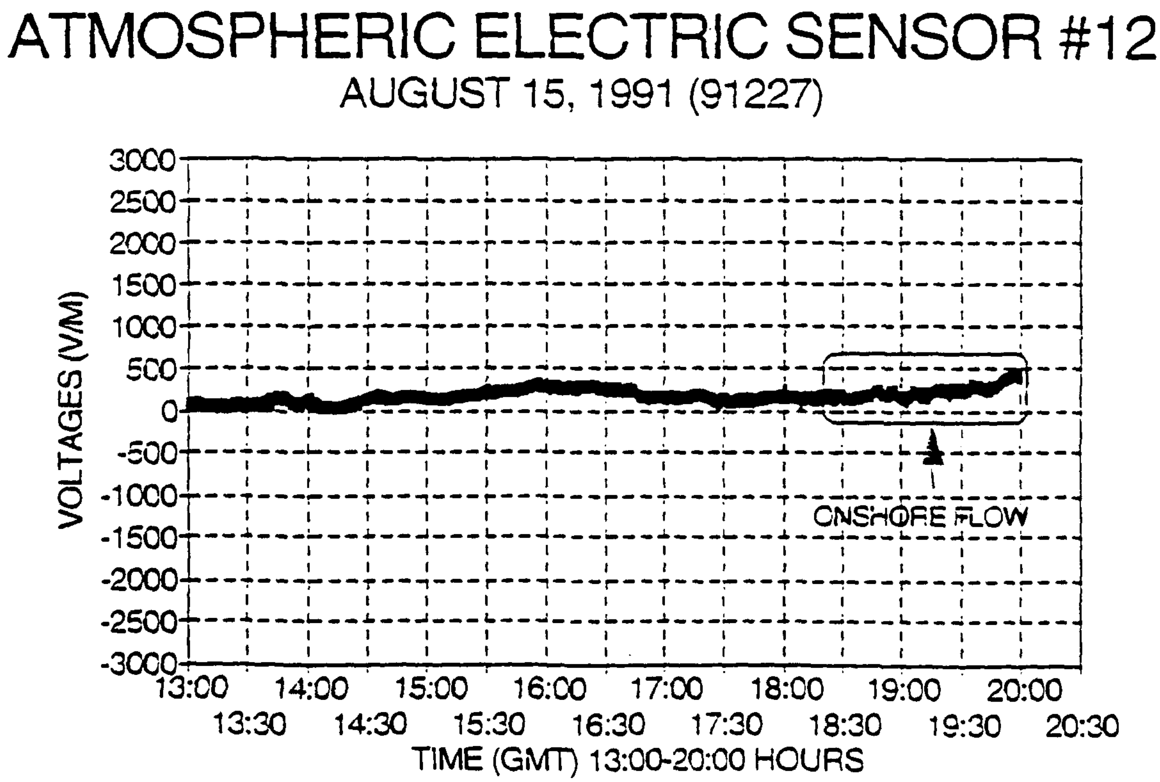

ATMOSPHERIC ELECTRIC SENSOR #12
AUGUST 15, 1991 (91227)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
ONSHORE FLOW
13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00
13:30 14:30 15:30 16:30 17:30 18:30 19:30 20:30
TIME (GMT) 13:00-20:00 HOURS

FIGURE 37

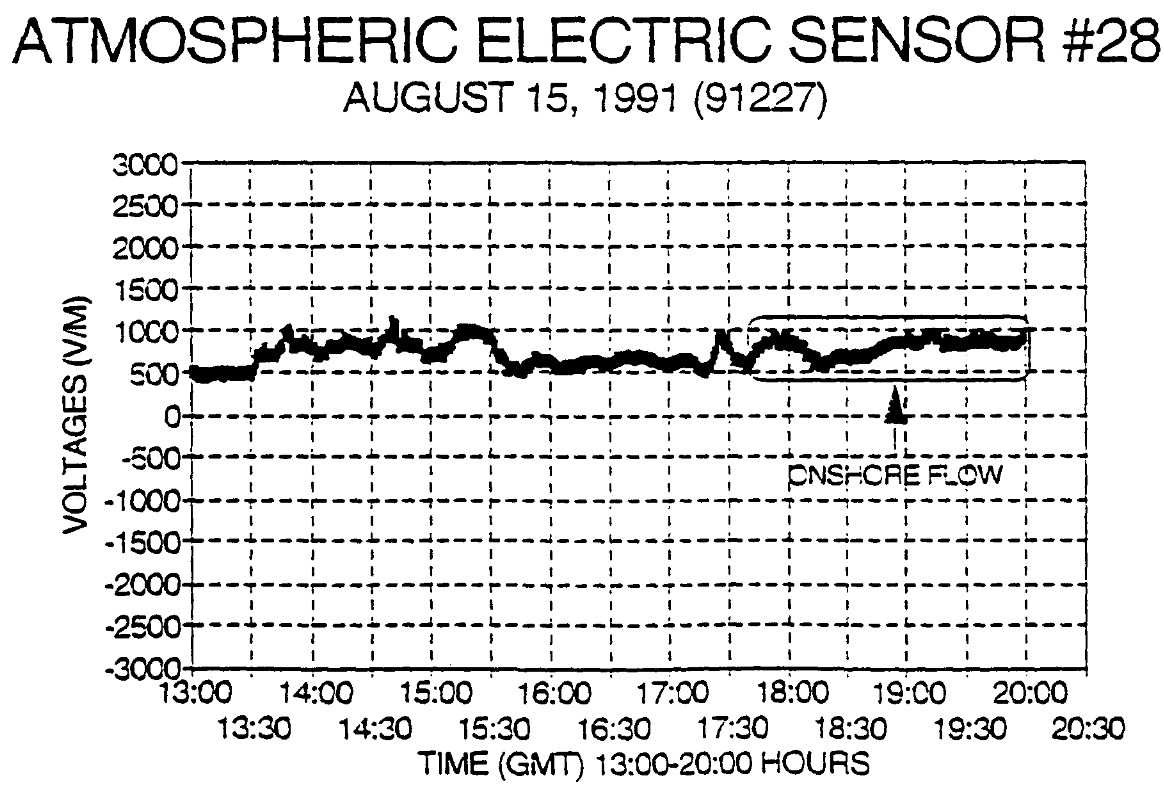

ATMOSPHERIC ELECTRIC SENSOR #28
AUGUST 15, 1991 (91227)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS

FIGURE 38

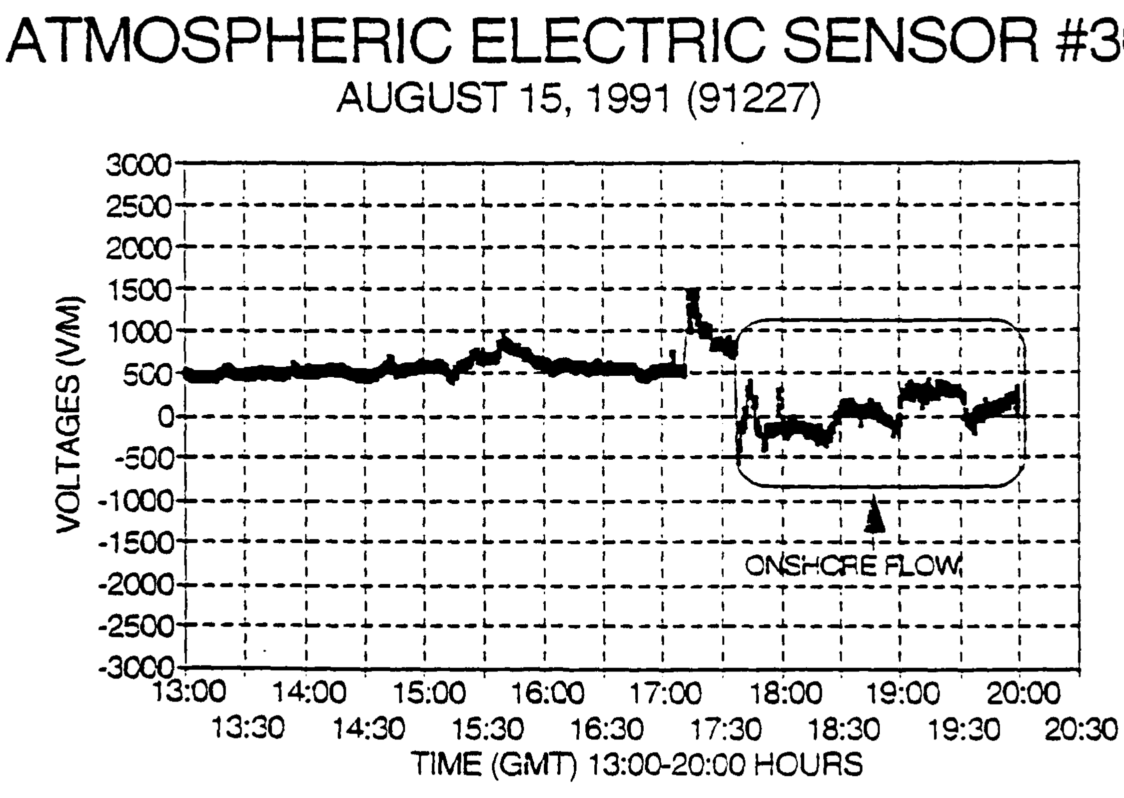
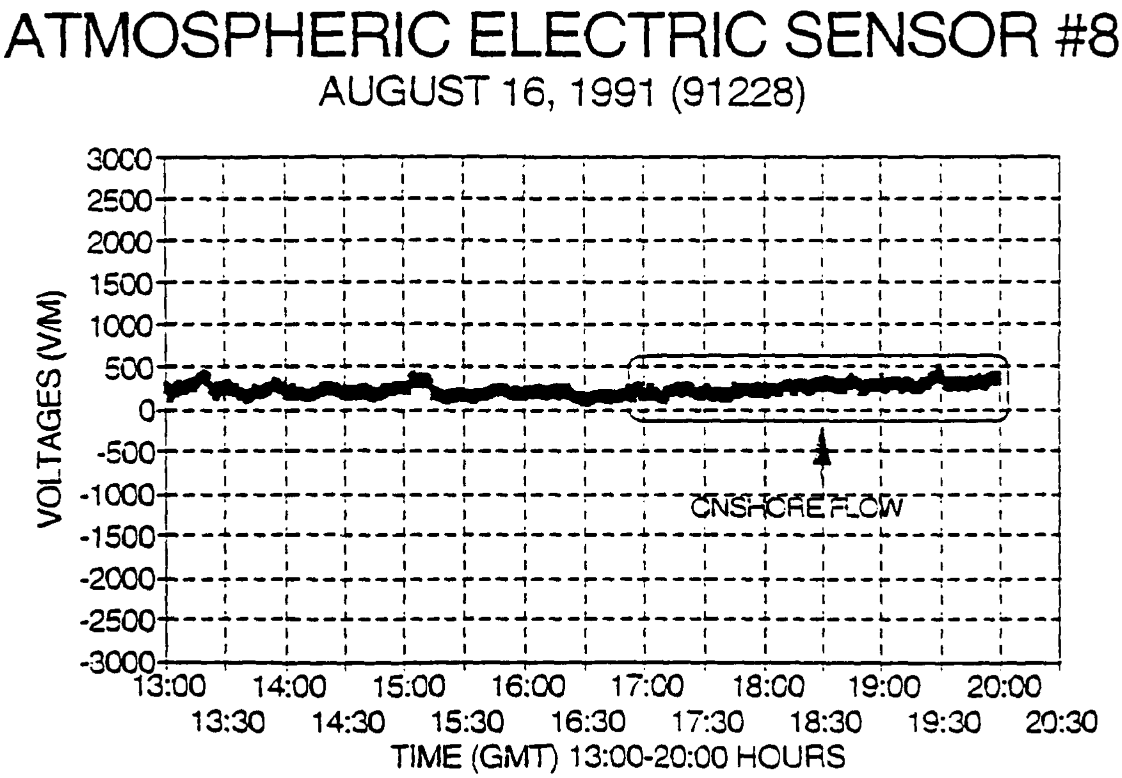

ATMOSPHERIC ELECTRIC SENSOR #30
AUGUST 15, 1991 (91227)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS
ONSHORE FLOW

FIGURE 39



ATMOSPHERIC ELECTRIC SENSOR #8
AUGUST 16, 1991 (91228)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS

FIGURE 40

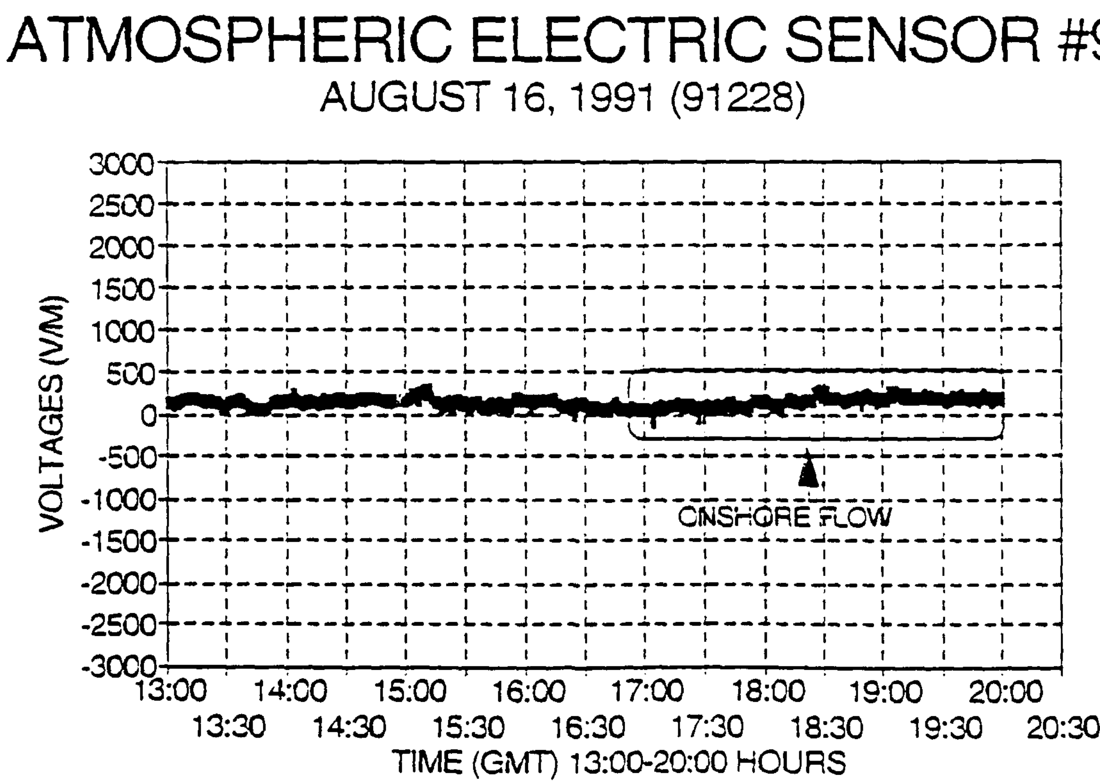

ATMOSPHERIC ELECTRIC SENSOR #9
AUGUST 16, 1991 (91228)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
VOLTAGES (V/M)
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS

FIGURE 41

ATMOSPHERIC ELECTRIC SENSOR #12

AUGUST 16, 1991 (91228)

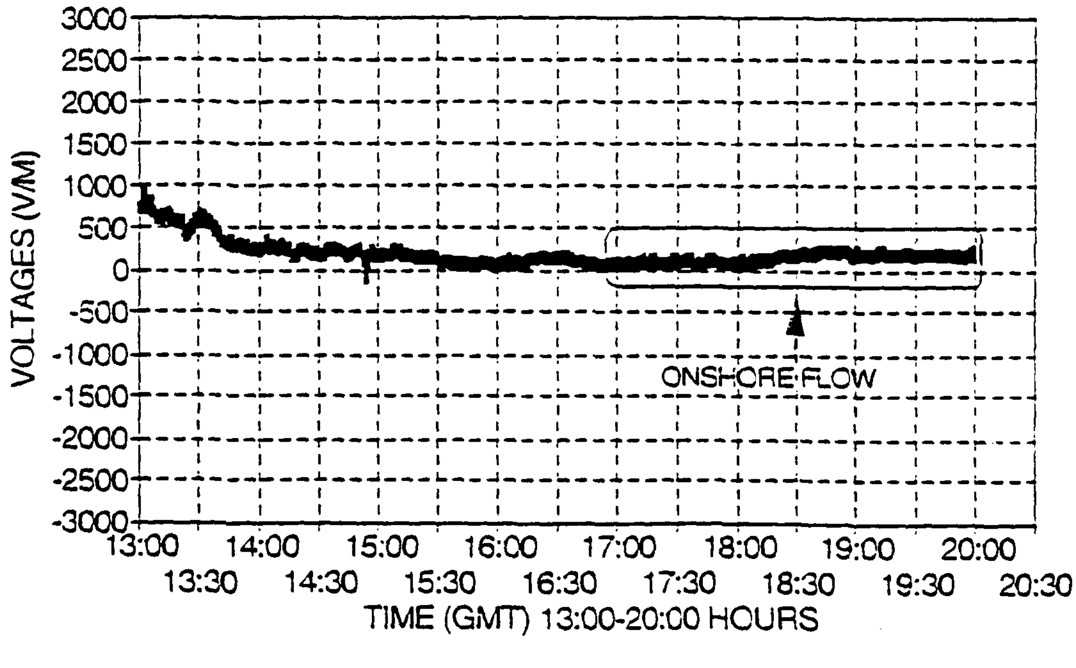


FIGURE 42

ATMOSPHERIC ELECTRIC SENSOR #28

AUGUST 16, 1991 (91228)

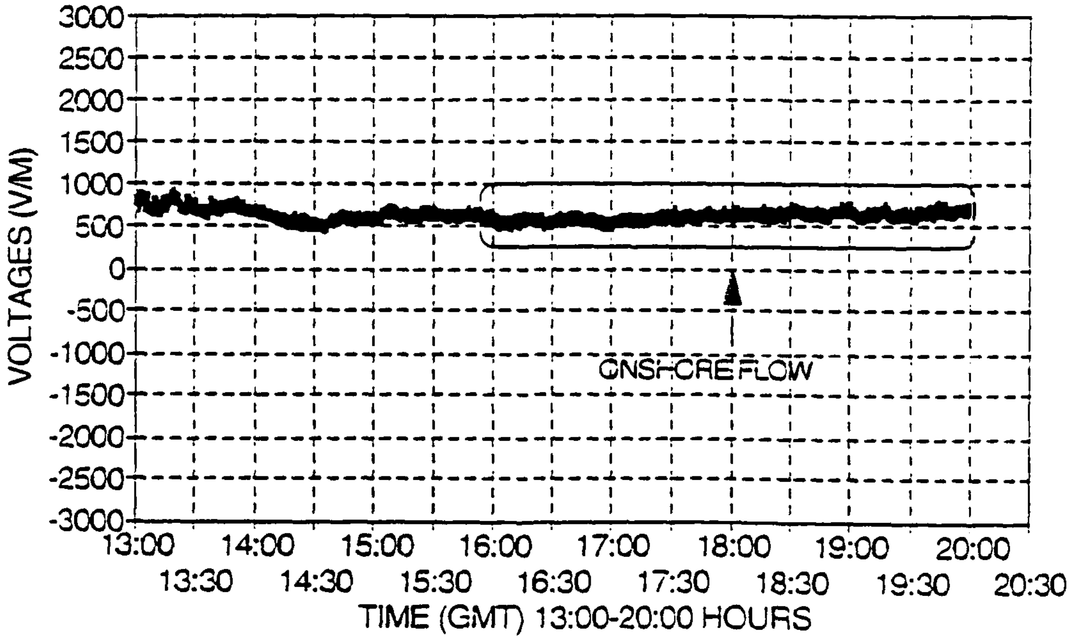
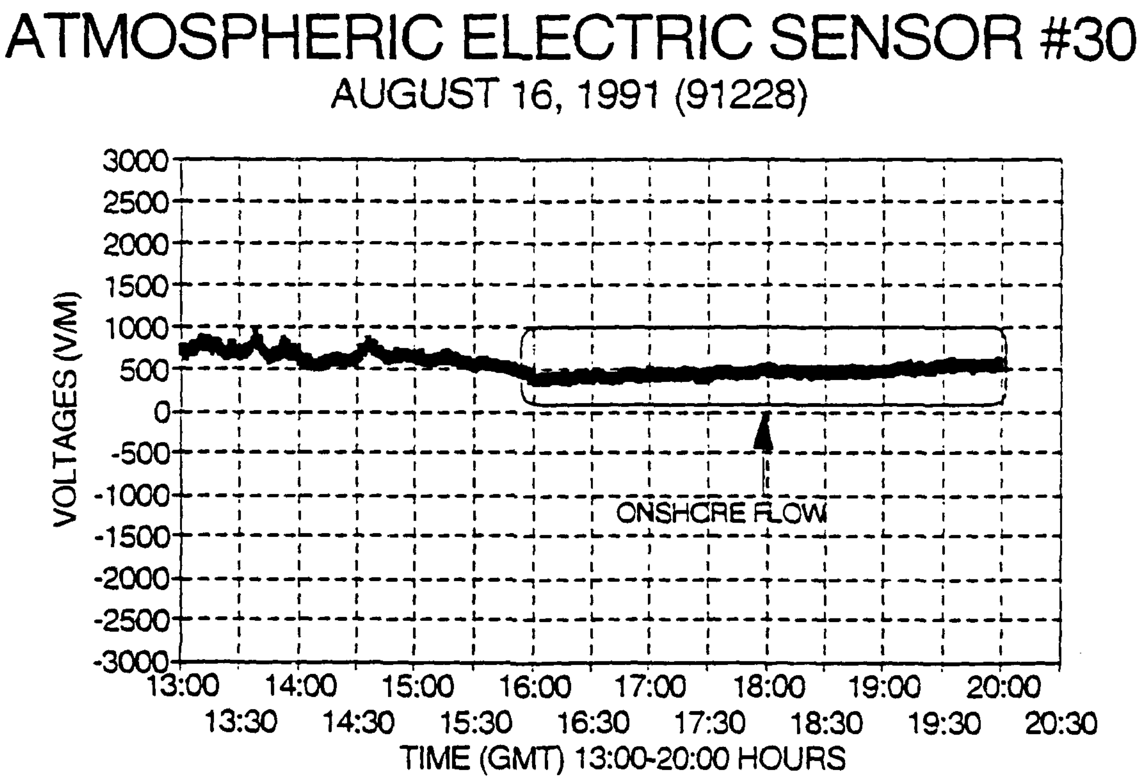


FIGURE 43



ATMOSPHERIC ELECTRIC SENSOR #30
AUGUST 16, 1991 (91228)
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
ONSHORE FLOW
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 13:00-20:00 HOURS

FIGURE 44

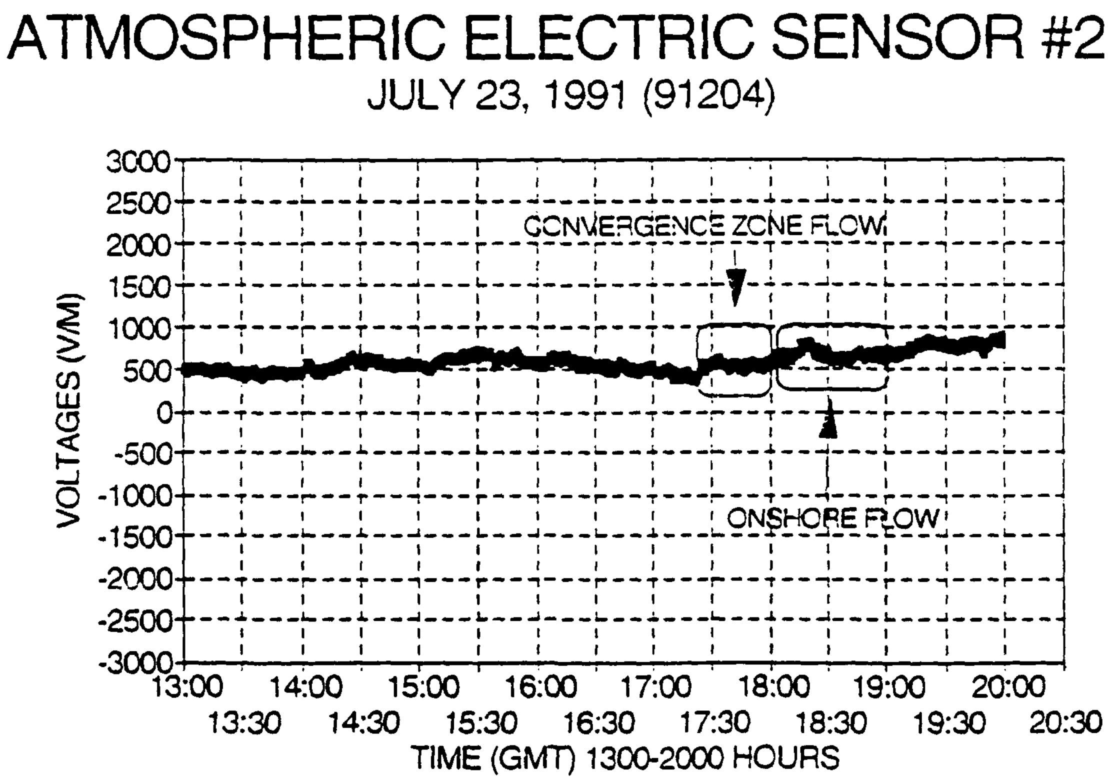

ATMOSPHERIC ELECTRIC SENSOR #28
JULY 23, 1991 (91204)
CONVERGENCE ZONE FLOW
ONSHORE FLOW
VOLTAGES (V/M)
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
13:30
14:30
15:30
16:30
17:30
18:30
19:30
20:30
TIME (GMT) 1300-2000 HOURS

FIGURE 45

ATMOSPHERIC ELECTRIC SENSOR #30

JULY 23, 1991 (91204)

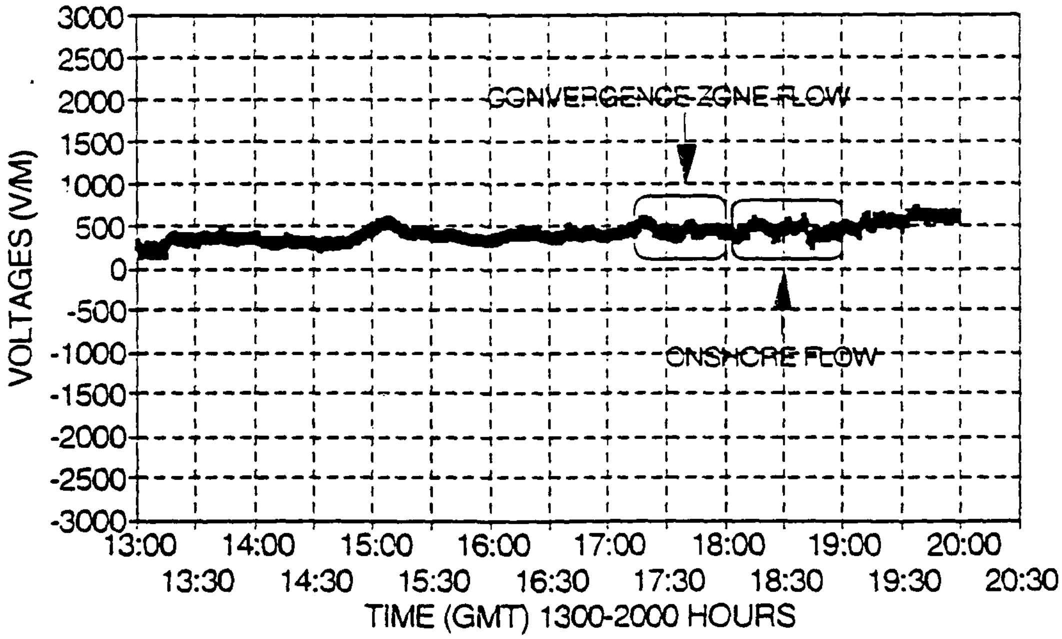


FIGURE 46

REFERENCES

Abe, S., and T. Yoshida, 1982: The effect of the width of peninsula on the sea breeze. **J. Meteor. Res. Japan**, 60, 1074-1084.

Blanchard, D.C., 1963: Electrification of the atmosphere by particles from bubbles in the sea. **Prog. Oceanogr.**, 1, 71-202.

_____, 1966: Positive space charge from the sea. **J. Atmos. Sci.**, 23, 507-515.

Blanchard, D.O., and R.E. Lopez, 1985: Spatial patterns of convection in south Florida. **Mon. Wea. Rev.**, 113, 1282-1299.

Byers, H.R., and H.R. Rodebust, 1948: Causes of thunderstorms of the Florida Peninsula. **J. Meteor.**, 5, 275-280.

Chalmers, J. A., 1967: Atmospheric Electricity. Pergamon Press, Oxford.

Christian, H.J., V. Mazur, B.D. Fisher, L.H. Ruhnke, et al., 1989: The Atlas/Centaur lightning strike incident. **J. Geophys. Res.,** 94, 13170-13177.

Cooper, H.J., M. Garstang and J. Simpson, 1982: The diurnal interaction between convection and peninsula-scale forcing over south Florida. **Mon. Wea. Rev.**, 110,486-503.

Cunning, J.B., R.L. Holle, P.T. Gannon and A.I. Watson, 1982: Convective evolution and merger in the FACE experimental area: Mesoscale convection and boundary layer interactions. **J. Appl. Meteor.**, 21, 953-977.

Estoque, M.A., 1962: The sea breeze as a function of the prevailing synoptic situation. **J. Atmos. Sci.**, 19, 244-250.

Gatham, S. G., and E. M. Trent, 1968: Space charge over the open ocean. **J. Atmos Sci.**, 25, 1075-1079.

_____, and W. A. Hoppel, 1970: Electrification processes over Lake Superior. **J. Geophys. Res.**, 75, 1041-1048.

Foote, G. B., 1991: Scientific Overview and Operations Plan: CaPE, Convection and Precipitation/Electrification Experiment. National Center for atmospheric Research, Boulder, Colorado.

Frank, N.L., P.L. Moore and G.E. Fisher, 1967: Summer shower distribution over the Florida peninsula as deduced from digitized radar data. **J. Appl. Meteor.**, 6, 309-316.

Gentry, R.C., and P.L. Moore, 1954: Relation of local and general wind interaction near the sea-coast to time and location of air-mass showers. **J. Meteor.**, 11, 507-511.

Lopez, R. E. and R. L. Holle, 1987: The distribution of summertime lightning as a function of low-level wind flow in central Florida. NOAA Technical Memorandum ERL ESG-28, Environmental Sciences Group, Environmental Research Laboratories, Boulder, Colorado, 43 pp.

Maier, M. and L. Maier, 1992: Absolute calibration of the 45th space wind field mill instrument. Technical Report National Aeronautics and Space Administration, Kennedy Space Center, Florida.

Moran, J.E. and Morgan M.D., 1991: Meteorology: The Atmosphere and the Science of Weather. Macmillan Publishing Company, New York, New York.

Neumann, C.J., 1971: Thunderstorm forecasting at Cape Kennedy, Florida, utilizing multiple regression techniques. NOAA Technical Memorandum NWS SOS-8, Space Operations Support Division, U.S. Department of Commerce, Silver Springs, Maryland, 44 pp.[NTIS COM-72-10237.]

Neumann, J., and Y. Mahrer, 1975: A theoretical study of the land and sea breeze curculation. **J. Atmos. Sci.**, 28, 532-542.

Nicholson, J. R., and W. Jafferis, 1988: Atmospheric Sciences Program at NASA Kennedy Space Center. Preprints: AIAA 26th Aerospace Sciences Meeting, Reno, Nevada, American Institute of Aeronautics and Astronautics, Paper No. AIAA-88-0197.

Pierce, E. T., 1992: Storm Electricity and lightning In Thunderstorm Morphology and Dynamics. ed. by Edwin Kessler. University of Oklahoma Press, Norman, OK.

Pielke, R.A. and M. Segal, 1986: Mesoscale circulations forced by differential terrain heating in Mesoscale Meteorology and Forecasting. ed. Peter S. Ray, American Meteorological Society, Boston, MA.

Pielke, R.A., 1974: A three-dimensional model of the sea breezes over south Florida. **Mon. Wea. Rev.**, 102, 115-139.

Reible, D.D., J.E. Simpson and P.F. Linden, 1993: The sea breeze and gravity-current frontogenesis. **Q. J. R. Meteorol. Soc.**, 119, 1-16.

Rogers, Jeffery C., 1991: Geography 623.02 Synoptic Meteorology: Severe Storm Forecasting by Radar and Satellite. The Ohio State University, Columbus, Ohio.

Rust, W.D. and D.R. MacGorman, 1988: Techniques for measuring electrical parameters of thunderstorms In Instruments and Techniques for Thunderstorm Observation and Analysis. ed. by Edwin Kessler. University of Oklahoma Press, Norman, OK.

Schaefer, J.T., L.R. Hoxit and C.F. Chappell, 1992: Thunderstorms and their mesoscale environment In Thunderstorm Morphology and Dynamics. ed. by Edwin Kessler. University of Oklahoma Press, Norman, OK.

Simoncic, A. A., 1983: Weather Support to the Space Transportation System. Preprints: 9th Conference on Aerospace and Aeronautical Meteorology, June 6-9, Omaha, NE American Meteorological society, Boston, 348-353.

Studies in Geophysics, 1986: Studies In Geophysics: The Earth's Electrical Environment. National Academy Press, Washington, D. C.

Ulanski, S.L. and M. Garstand, 1978: The role of surface convergence and vorticity in the life cycle of convective rainfall. Part I: Observations and analysis. **J. Atmos. Sci.**, 35, 1047-1062.

Wahlin, L., 1986: Atmospheric Electrostatics. Research Studies Press, Letchworth, Hertfordshire, England.

Watson, A.I., R.L. Holle, R.E. Lopez and R. Ortiz, 1991: Surface wind convergence as a short-term predictor of cloud-to-ground lightning at Kennedy Space Center. **Wea Forecasting**. 6, 49-64.

_____, R.E. Lopez, R.L. Holle and J.R. Daugherty, 1987: The relationship of lightning to surface convergence at Kennedy Space Center: A preliminary study. **Wea Forecasting**. 2, 140-157.

_____, R.L. Holle, R.E. Lopez and J.R. Nicholson, 1991: Surface wind convergence as a short-term predictor of cloud-to-ground lightning at Kennedy Space Center: a four-year summary and evaluation. Proceedings, International Conference on Lightning and Static Electricity, April 16-19, Cocoa Beach, FL, 76-1 to 76-10.

______, and D.O. Blanchard, 1984: The relationship between total area divergence and convective precipitation in south Florida. **Mon. Wea. Rev.**, 112, 673-685.

______, R.L. Holle and D.O. Blanchard, 1983: The relationship between total area divergence and convective precipitation in south Florida and Illinois. Preprints: 9th Conference on Aerospace and Aeronautical Meteorology, Omaha, Nebraska, Amer. Meteor. Soc., 106-111.

Weber, Harry P., 1992: Contract F08606-88-C-0014; field mill calibration teleconference summary. Correspondence to the 45th Space Wing Maintenance Squadron/MARS, Patrick Air Force Base, Florida.

Weems, J., N. Wyse, J. Madura, M. Secrist, and C. Pinder, 1991: Assessment and forecasting of lightning potential and its effect on launch operations at Cape Canaveral Air Force Station and John F. Kennedy Space Center. Proceedings, International Conference on Lighting and Static Electricity, April 16-19, Cocoa Beach, FL, 77-1 to 77-11.

Williams, S.F., K. Caesar, and K. Southwick, 1992: The Convection And Precipitation Electrification (CaPE) Operations Summary And Data Inventory. Published by the National Center For Atmospheric Research Office Of Field Project Support, Boulder, Colorado.

Wilson, C.T.R., 1925: The electric field of a thundercloud and some of its effects. **Proc. Phys. Soc. London 37**: 32D-37D.

______, 1926: Discussions of the electrical state of the upper atmosphere. **Proc. R. Soc. London 3**: 1-13.

Woodcock, A. H., D. C. Blanchard, and C. G. H. Rooth, 1963: Salt-induced convection and clouds. **J. Atmos. Sci.** 20, 159-169.

OHIO STATE UNIVERSITY

The Ohio State University
Graduate School

247 University Hall
230 North Oval Mall

Phone 614 292-6031

Master's Thesis Approval

Final approval of the master's thesis occurs after the student has satisfactorily completed the Master's Examination. One copy of the thesis, two copies of the abstract and the Thesis Approval form must be submitted to the Graduate School no later than one week before commencement. The adviser must sign both the abstract and the title page of the thesis.

Subsection 8-11 of the Graduate School Handbook pertains to the master's thesis.

555-43-4681

Student information (please type or print)

Name (Last, First, Middle): Taijeron , Sabrina Judith

Academic Unit: Atmospheric Sci.

Degree Name (M.A., M.S., etc.): Master of Science

Thesis Title: The Sea Breeze Convergence Zone And Its Relationship To Fair Weather Electricity In East Central Florida

Thesis Approval

By signature, the members of the Master's Examination Committee approve the thesis of the student named above and recommend that it be accepted by the Graduate School in partial fulfillment of the requirement for the master's degree.

Jeffrey C. Rogers
Student's Adviser

Date: June 2, 1993

Jay S. Hobgood

[illegible]

The Ohio State University
Form [illegible] Revised [illegible]

White Copy — Graduate School (submit)
Canary Copy — Graduate Studies Committee Chairman (retain)

MASTER'S THESIS ABSTRACT

THE OHIO STATE UNIVERSITY
GRADUATE SCHOOL

(Please type all information requested. The margin requirements are the same as those for the text of your thesis.)

NAME: Taijeron, Sabrina J.
(Last, First Middle)

QUARTER/YEAR: Spring 1993

DEPARTMENT: Atmospheric Sciences

DEGREE: Master's of Science

ADVISER'S NAME: Dr Jeffrey C. Rogers

THESIS TITLE: The Sea Breeze Convergence Zone And Its Relationship To Fair Weather Electricity In East Central Florida

Summarize in the space below the purpose and principal conclusions of your thesis. Please single space and do not exceed 100 words.

This research focused on the relationship between the fair weather electric field and the sea breeze convergence zone at the KSC/CCAFS. Wind sensor and electric field mill data from the CaPE project were analyzed. This study did not reveal any clear indication of a higher electric field during sea breeze convergence. The two phenomena exist, but their interactions would appear to be weak. The expected interaction might be found in bigger data sets or through other types of analysis.

Jeffrey C. Rogers

Adviser's Signature